Aalto University
School of Arts, Design
and Architecture

GENERATIVE SOUND DESIGN:

COMPLEXITY, REALNESS, AND QUALITY

***INCLUDING STUDY CASES OF
AN INTERACTIVE 3D ENVIRONMENT SOUND RESEARCH
AND A GENERATIVE SOUND INSTALLATION***

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Abstract

This thesis introduces the process of designing generative sound through the attributes of sound design complexity, realness, and quality. Along with the definitions of these attributes, the methods of the generative sound design process are discovered. This process and analysis is also presented in practice with two study cases: a 3D environment with a generative sound design perception comparison user test and a generative sound installation on a location.

By means of the study cases and the interviewed professionals within the sound field, this thesis discovers how the generative sound design is defined and perceived. The user test examines whether the generative sound design enhances the experience and the interactivity. It also provides the answers to whether people notice sound generativity and the difference in sound design quality during an interactive and engaging experience; especially in what way and what results from their reaction, is studied. The possible similarities in the users' experiences and perception are also presented.

In order to evaluate the process of designing generative sound, the methods and behaviour within the sound design require understanding. The functions and elements within the generative sound design and sonic interaction are therefore reviewed. Whether or not it is important to get new media to use generative sound design, this text guides to evaluate the advantages and disadvantages of generative sound design processes and methods, including the benefits and challenges of implementing generative sound designs.

This thesis also includes a Blu-Ray material with videos and photos of both study cases in order to demonstrate how the generative sound design was exhibited and researched. From the photos and videos, the reactions of the users and listeners can also be seen.

More specific information about the generative sound installations and exhibitions can be found on the website: http://kirsiihalainen.com.

Keywords Generative Sound Design, Quality, Complexity, Realness, Sound Art, Game Audio, Procedural Audio

1. Introduction

Sound design, and the many levels of it, is still quite obscure and mysterious to many as a creative process. It is hard to define a really good sound design and the methods of how to create one. Furthermore, some of the terms within the sound design processes are often vague; therefore, the meanings lack preciseness (Sterne, 2012). The terms to describe different sound behaviours are not used in a coherent way among sound designers and often some of them are not recognised or even heard of, because “knowledge is a problem in the sound studies” (Sterne, 2012). According to Professor Sterne there are at least three different problems. Firstly, knowledge is a “problem of epistemology and method”. Second, there are several knowledges of sound competing, and thirdly, knowledge “is situated among vectors of power and difference”. (Sterne, 2012, p.8.) I would also add a fourth problem; not all people working in the field have ever even studied sound. However, I agree with Sterne that psychoacoustics, sound technologies, and the knowledge between normal and abnormal hearing have been studied extensively. Furthermore, there are also sound studies not restricted to science, and from different fields. Together these studies form the knowledge of sound and will continue moulding it in the future. Therefore, we should challenge the sound terms of today; “We must not automatically take any discourse about sound in its own terms but rather interrogate the terms upon which it is built. We must attend to the formations of power and subjectivity with which various knowledges transact.” (Sterne, 2012, p.9.) Even though the term generative processes has a long history in music, the norm of it in sound design is still something new, and the meaning of it is still not obvious among the people working within the industry. I will face this challenge by defining the *generative sound design,* and I have chosen the terms *complexity, realness* and *quality* through which I will explore it.

It is not obvious whether the problems of knowledge will directly affect the problems of being able to hear what sounds good or bad. Nevertheless, a problem might occur, when a person, whose ears are not trained, is creating sounds: will this person be able to distinguish the differences between a good sounding piece or composition and a bad one? Whether a sound designer could be trained to hear the difference, or if he/she needs a certain “sound oriented talent”, is also a question to contemplate. Because people perceive things differently, personally, and with a subjective point of view, it creates challenges to determine the factors of producing a sound design of a good quality (Aro, 2006). Also the misinterpretation of the verbal evaluation of sounds becomes problematic. The cause may be the influence of the different backgrounds of the listeners and their varying emotional impacts to the sound.

Still, when excluding music, sounds are considered to have a supporting role in the media, and not as a quality enhancer. This holds especially true with new media consisting of interactive applications and platforms, such as computer and mobile games, multimedia software, installations or interactive films (Collins, 2013). Sounds are completely neglected on web pages and features online because of their irritative reputation. This has lead to a situation that the possible benefits of sound design in new media are somewhat underestimated, or the sound is produced only to support the image (Collins, 2008). Sound has been considered as a necessary evil; people are not aware of the power that sound possesses. According to the famous filmmaker David Lynch, it is good to remember that “Films are 50 percent visual and 50 percent sound. Sometimes sound even overplays the visual.” (Monster Cable, 1998.) Despite this, the benefits of having good sounds are overlooked because there is no proof or established standards of what defines the quality of the perceived sounds or sound designs. This is still a big debate in the sound industry field today (Ikonen, 2011). The risk exists that the sound designers’ work will be completely disregarded, like for mobile game sounds, as Collins (2013) states, “Social networking and mobile media have had interesting consequences for game sound, since both forms of casual games are often played with the sound turned off” (Collins, 2013, p. viii).

Even more challenging is when the role of sound is changed from purely functioning as a feedback feature to providing an entertaining experience. Sound can truly enhance the quality of an entire project and possibly also adds a “wow” factor to it, benefiting the production in many ways (Marks, 2001). These benefits simply have not been officially recognised or accredited. I personally think that the change is coming and soon the benefits can be acknowledged. We are living in a sound design phase, where it needs to prove its worth. This means that the importance of sound design quality is higher than ever; change is up in the air.

It is understandable when creating good sound design to a project that it is not only an arduous process, but an investment. The budget for sound design is often small and usually left as the last in line, maybe has no budget at all, or the people of the project are reluctant to take technical accessory risks when it comes to sounds. As a result the sound design might not fulfil the requirements of good quality. (Lapington, 2006.) These quality requirements suffer tremendously, if the sound designer will not spend enough time on creating sounds and editing them, making them technically as clear and clean as possible. If the sound design is not done properly, the outcome often results in incompetent sound work.

The technical aspects of an audio file are however not enough to create a quality sound design. There is no single recipe to implement or explain sound quality, quality in sound design, and quality in generative sound design processes. More factors are needed than just the frequency, wavelength, wave number, amplitude, sound pressure, sound intensity, speed of sound, direction of sound, and all other scientifically measured values of sound. Instead, emotional impact, purpose, aim, story, aspiration, and many other factors are needed for the design. Nonetheless, it is important to discover the impact of sound on the experience, how it affects the feelings, and the impact of sound design during interactivity.

As many opinions as there are about the quality of music there are also about sounds. Sounds for films have been studied for a long period of time, especially from the technical perspective. It is much easier to discuss audio technical preciseness in quality than the perceived sound quality (Aro, 2006). The quality in the perception psychology is much harder to measure than the technical sound quality. This means that when talking more deeply about sound quality in sound design, it is not unequivocal. However, I have been pondering the subjectivity of perceiving sound and wondering if there are some unifying factors. I would state the public and audience expectations as one of these factors, since even if the audience does not have a “direct experience what something actually sounds like but nonetheless have highly developed expectations of what it should sound like” (Gibbs, 2007, s.86). Therefore also the sound designer should be able to detect what these expectations are and be able to realise them, even if he/she were to make a conscious decision of a differing outcome. That being said, I believe there are a lot more unifying factors than acknowledged in the perceptual experience of sound.

When it comes to films, the sound design is always a linear sound design process; it has a beginning, middle and an end. This means that in a linear sound design process, the sound design is done only once, whereupon planning is straightforward and the quality process is mainly controllable. In contrast, the process of designing generative sound aims towards non-linear audio. During the non-linear process, the generative sound design requires several sound designs in parallel; the aim is to avoid sound repetition. When the sound designer at least doubles the sound design and increases the quantities of sounds, of course the time and effort escalates commensurately. However, most of the technical sound quality criteria are similar in both film and generative sound design, for instance the basic handling of sound files, editing, processing and creating the desired emotional impact. The actual outcome of the generated design is harder to plan, implement, mix and create with the desired impact.

The generative process obviously requires more effort from the sound designer. Audio manipulation skills are not enough; also additional expertise in programming generative processes is required, as well as the ability to stretch their knowledge beyond sound. According to Doctor of Philosophy Schnell (2013), “While many of the involved techniques belong to the domain of digital audio processing, the design of generative processes involved in audio rendering relies on models and formalisations that are also used in graphic animation and algorithmic techniques of composition (see for ex. [SIC] Wishart 1996; Supper 2001; Nierhaus 2009)” (p. 5-6). Because of the required expertise of a sound designer, the time-consuming sound handling, and the usage of a more complex technical process, the generative sound design needs justification. The benefits of a generative sound design process have to include a value of worth, albeit quality benefits are hard to name and specify.

Unfortunately, “less is more” does not apply in the generative sound design process; sound quantity has a direct impact on sound quality. The more sounds, the more real it becomes, to some extent. The problem lies in recognising this limit and the borders of realness as a way to measure the sound design. It is essential to comprehend the moment when the sounds become believable within their context, or are thought of as natural to the entirety that they are combined or created for. Plainly increasing the quantity of sounds may still not result in a good quality sound design. Nevertheless, generative sound design could be the first step towards sound designing of a good quality. I have noticed that many media platforms would definitely benefit from this form of sound design.

Generative sound design aims to avoid repetition in many contexts. Therefore, it is more than challenging to define how complex the sound design needs to be and how many different sound textures are needed in order to make the sounds sound never-ending or always changing. For instance, hearing and recognising a sound loop starting and ending or noticing the sound become boring is essential. This is actually very crucial when designing generative sounds, and it should be possible to master a way to manipulate sounds in order to create a sound illusion, where the sounds are heard as always changing.

Sound processing together with sound quantity and complexity can be construed with several meanings and outcomes. There are several distractions during perception, as sound is also a phenomenon with attributes of masking, diffusion, and overlapping. Problems occur when the quantity of sounds increases and the listener is only able to concentrate on the most important sound information (Aro, 2006). These problems always affect the final quality of the outcome, not to mention the impact and consequences of psychoacoustics in audio technical quality. This quality loss is inevitable and dependant on the output quality of the headphones or the speakers that the listener is using. To circumvent this, the audio should be packed to the digital media in such a way that the quality diminishes as little as possible when played back.

Far behind these terms and challenges comes interactivity that can be added to the sound and its features. Generative sound design becomes more complex when adding the interactivity to the generative algorithmic processes of the sound design in such a way that the design changes with or without full control. However, interactivity is not required to make a sound system generative. Neither is it certain that the perception of sound quality through the generative sound design automatically increases the positive experience of the interactivity. The way a user perceives the generative sound design, and the influences of generative sound design to the interactive experience, are quite unknown.

Among these problems lie the questions whether the average user notices the differences in the sound design quality, how complex the sound design should be according to the user, and what the benefits or disadvantages of generative sound design are. The goal in this text is to evaluate all these aspects and try to reveal how important the role of generative sound design has become in the media, because the beneficial norms for generative sound design have not been established.

1.1 My motivation

I have a long personal history with sound and music, I have gained experience in recording, mixing, and composing. I have also obtained programming experience with several programming languages, I build electronics, and I have experience in sensor technology. It has led me in creating sound installations and sound designs for different interactive multimedia. I would say my main interest is in the creation of sound designs and especially the actual art of the design. During my work as an audio engineer I have noticed that the audio-technical quality standards are self-evident, which is why they hold no particular interest to me. Instead, the fascination of the emotional effects of the sound design and its impact in the listener have beguiled me.

I have always been precise about the sound quality and demanded myself to create even more complex and grand sound designs. This has resulted in acts of simulating real-time and live sound events, which required the use of a generative sound design process. Ever since, generative sound design has been my objective and has turned into a research during my master of art studies; the research of the “ever changing” sound design.

I have noticed that the quality of the sound designs and the role of sound in most multimedia and installations have become neglected or disregarded. The potentials of sound design are simply underrated with a shrug. Not enough effort is made in order to increase the experience or the outcome enormously simply by having audio; either there is no sound or sound design, or there are only attached audio files from free samples. Therefore, I decided with this thesis to enlighten people of the power of sound and reveal the multilateral effects of a quality sound design.

The mentality of today, where people try to do everything themselves, results in not dividing the tasks within the project, especially according to the people’s real skills and talents. I have had people come and ask me to explain in two minutes how to make sounds and create a sound design for a specific media. This is of course a mission impossible, which is why it is important to understand that the creation of sounds, sound design, and audio engineering is a long study into audio technology and audio processing. A sound designer has to have the ability to understand the properties of sound, psychoacoustics, and also the features that the sound impacts, such as the narrative, interactivity, and so forth. Understanding sound only happens by doing, therefore it is time consuming. I would also state that the person involved with audio has to have a sense of sounds: what sounds good and what not; natural endowment, skill, or talent in sound. I would say that a musical background helps enormously, because the levels of understanding music behaviour also apply to sound. Nevertheless, technology or technical demands should not inhibit the creation of the sound design.

I recently read an article from Meteli magazine (1/2015) where Mikael Eriksson, who wrote his thesis about the theory of sound design, talks about the importance and definition of sound design. It is clear that the attitudes towards working with sound and sound design are changing here in Finland, and I believe that this is happening everywhere else as well, since I have noticed a change when following the conversations of various sound design groups in social media. Eriksson says that the attitudes toward sound design are neglecting the special knowledge of sound design, and that it is assumed that the skills and knowledge are the same to all fields of sound design; meaning only the field separates them from each other. I agree with Eriksson, and this is something that needs further discussion. It is simply impossible for someone without specialisation and further study to do sound design to all media formats and contexts. One specialisation among all others is the generative sound design. As Eriksson says, it is not about comprehending only the sound itself and its behaviour; it is about the relations to all the other elements of the work or in the project. This is the technical vs. psychological confrontation of sound processes, which I will talk about throughout this thesis. Sound design is the quality factor; without the design the sounds are only a compilation of some sounds that there are.

I have always wanted to take my expertise further, and my mentality is to have a long life experience with sound. As such, this thesis is my next step in finding something new in the field of sound design; therefore, generative sound design became my research. I believe it might have a huge impact on future sound designs, since a generative process can be easily utilised in the creation of more complex sound designs.

1.2 Generative audio

Generative audio is implemented with a process, where a computerised system generates the audio. The system generates new sounds or modifies sounds inserted into the system according to set rules. Due to this method of implementation, generative audio is mostly used in games and in sound art, but also interactive cinema has started to utilise it. The process of creating sounds in games in similar ways is often referred to as adaptive audio (see chapter 2.3.1). However, the meaning differs, since nowadays the features of game audio are more than just adaptive audio. Procedural audio (see chapter 2.3.3) is also making its way to game audio engines.

The aim with generative and procedural audio is to create new and always, at least a little, different sounds in real-time, especially while being played over and over again. In sound art, the different generative art forms usually function as input or values in the system; the system focuses on generating something new and unpredictable from almost anything using mathematics or algorithms (see chapter 2.3.2). Generative music is the known form of generative audio. Not only sound effects and sound ambiences, but also music and even dialog with systems using an artificial intelligence (AI), can be used as the sound material for generative audio. Interactive cinema focuses more on the different parallel versions of the same film, including the interactivity of the audience to choose from these parallel options to continue the film. Therefore generative sound can be thought of as compiled of parallel versions. All of the above audio features are related to generative audio and can be used as the generative sound design process.

1.2.1 Generative music

Generative audio and especially generative music is a phenomenon, which has been known for a long time, as the earliest speculated generative music instrument was the Aeolian harp from ancient Greece, which is played by the wind. The harp was first introduced by priest Athanasius Kircher in 1673. Later on, during the late 18th century, a musical dice game called Musikalisches Würfelspiel became popular. The numbers of the dice indicated the short sections of music, which then would be played in the order of the thrown dice numbers. (Larsen, 2008.) It has been alleged that Mozart was behind this musical game. This way of playing sections with the random outcome would also be called generative.

However, the actual rise of the generative music started much later, in the 1940s, when Muzak developed the first elaborate music system (Garton, 1996). Gradually after that, in the 50s, generative music pioneers, such as John Cage, used randomness as the core element in their music, and during the 80s, Brian Eno created the concept of generative music computer software (Larsen, 2008). Therefore, the term generative music became known from Brian Eno's composition processes (Priestley, 2014). Later, generative music evolved into a computerised system that would always change the music to be different all the time.

The composition of generative music consists of different algorithmic methods, such as artificial intelligence (AI) sound, stochastic sound, and procedural audio. These terms will be explained later in chapter 2.3. With these methods, it is possible to control the generative actions of the music and define the rules of composing. Normally, generative music is composed by a computer through these methods; the computer is the composer.

Currently, generative music is still popular in the music and sound art scene. The "music" is constructed more or less from uncommon sounds and not with traditional instruments. Because of this, generative music as a term has been challenged and some artists would like to change it; the limit between generative sound design and generative music has become blurry. The sound sources for the generative music can be as complicated as plants, giving values which are generated into sounds, or sounds are created with neuroscience from the brainwaves; the possibilities are endless. The new and more complex development of the technology makes it possible to grab the values of anything imaginable and turn those parameters into sounds and music.

Figure 1.1 The setup for sonifying plants into music by sound artist Mileece (Aaronson, 2014).

1.2.2 Sound art

The first computerised sound installations were made for playing compositions of sounds. Therefore generative sound installations are often made with sounds that create music or sound environments. This means that the term generative sound art may refer to musical sounds or to sounds that create music, but it will also refer to sound installations with sound effects or soundscapes that are played. Sound art and sound installations are nowadays using more ways of generative processes in order to create sounds and soundscapes that have not been heard before, or to create sounds that slightly change in order to avoid repetition in the sound design. The development of technology drives the sound art; it finds the meaning within the technology and reconstructs the sensuousness in communication with virtuality (Chagas, 2006).

There are several topics into which the sound art can be divided. Most of these topics can be easily transformed into generative sound art. However, generative sound art always requires either processing with a computerised system or a technical system with generative features and means. With the taxonomy of audio divided into topics and fields created by Chagas, it is easier to inspect the sound art field and see the differences within the field.

TAXONOMY OF SOUND ART

I – Topics:	
Sound synthesis and processing	Computer-based software for sound analysis and synthesis, signal processing, programming, sound design, sound editing, sound mixing, algorithmic composition, performance systems
Sound space	Sound spatialization and reverberation, construction and simulation of sound spaces in physical, virtual and network environments
Audio environments	Multi-channel audio environments, surround environments (5.1, DVD), sound installations, virtual reality, immersion
Interfaces	Enhanced traditional instruments, MIDI-instruments, sensors, gesture and audiovisual interfaces
Interactivity	Interactive systems for composition and performance, systems of interactive communication in both real and virtual environments allowing the emergence of new artistic behaviours
Multimedia	Connections between acoustic and other art systems: visual, kinetic, scenic, architectural, etc.
Network	Network and interactive systems for production, storage, retrieval, and distribution of acoustical and musical content
Telematics	Telematic systems, devices and instruments for interactive and mobile composition and performance in real and virtual environments
Interculturality	Cognitive processes (hearing, composition, musical praxis), musical meaning, gestures, social functions, cultural exchanges

II – Fields:	
Medium-specific sound art	E.g.: radio art, acoustic art, soundscapes, acoustic environments, Web (audio and MIDI applications), mobile devices
Medium-spreading sound art	E.g.: film, theater, opera, dance, video, video game, audiovisual environments and installations (lasers, holography, etc.)
Performance sound art	E.g.: sound engineering, sound projection, sound-design (as performance), set-up design, sonic performance in interactive and multimedia environments (musicians, DJs, dancers, etc.)
Technical-scientific sound art	E.g.: signal processing, sound-design, virtual audio design, interface design, sound space design, computer aided composition (analysis and synthesis), music languages, performance software, acoustic ecology

Figure 1.2 Taxonomy of sound art (Chagas, 2006, p.143-144).

The generative sound art of today utilises different other aspects of generative art, such as creating for interactivity with haptics: generative sound sculptures, canvas, and wearable electronics. It has become popular in generative sound art to use electronic sensors, such as temperature, accelerometer, light, and pressure. The usage and development of different tools and technology has driven the sound art for many years. Recently sound-artistic ways of working with technology have created new innovative inspirations in the field of audio that interest the companies in the multimedia, phone, and game industry. In addition, new innovative ways to create sounds from different materials, spaces, and objects are the key interest in today's sound art, for instance, the Theometrica by Oscar Palou and Alexander Müller-Rakow in figure 1.3.

Figure 1.3 The generative and interactive sound installation, Theometrica, a synthesis instrument inspired by acupuncture (Visnjik, 2014).

1.2.3 Game audio

The first featured generative sound or music in games started to appear during the 90s. One of them was BallBlazer by Lucasfilm, which used a generative melody, and also Monkey Island, which used the interactive music system iMuse (Weir, 2014). Along the development of adaptive audio engine software for sound design in games, the generative processes have become more common. Today, games utilise 3D audio, and also Binaural sound worlds with head-related transfer functions (HRTF) are gaining popularity.

The video game industry has started to realise the possibilities to enhance the gaming experience and to acknowledge the benefits to the experience through a more complex sound design. The use of generative sound engines that modify or recreate new generative sounds based on mathematics or logistics has increased (Collins, 2013). This generative sound design process has become more known in the development of the computer game industry, because user-centred interactivity plays one of the key roles in generative sound design, and games utilise this feature more than any other media at the moment (Reiter, 2011). The commerciality of the game industry pushes the development of the game technology, and the creation of more powerful hardware; also the sound design and technology is being advanced along with the other game development.

The game audio teams are growing even bigger, and the audio quality in games is a process well monitored. An audio lead, sound designers, audio programmers, and audio quality assurance persons along with a composer(s), and sound interns work in the game companies' audio teams. The actual audio production process in games is a little different from films; the production process's main components in console games are music, sound effects, and dialogue in each category: pre-production, production, and post-production (Collins, 2008). During the pre-production stage, the audio team creates the audio design documents, and according to these cue sheets and design asset lists records and creates the sounds during the production. The post-production phase is the mixing phase of the audio in the game. This structural, organised and collaborative game audio process among an audio team with a variety of different skills enables the sound design quality to increase and therefore enhance the player experience (Collins, 2008).

Figure 1.4 An example of a setup for creating sounds and music for a game (Sherwani, 2011).

During this generation, the designing of games and even the creation of an entire game is going towards generative systems. Games may now also be based on generativity with the visuals and the game design. Generative games or procedurally-generated games are becoming popular as a game constructing process. The created virtual worlds for the player to discover within the game have grown enormously, and the possibilities and options in the game are becoming endless. Some examples of these procedurally-generated games with huge virtual worlds are *No Mans' Sky* which is currently being developed by Hello games, *Secret Habitat* (released 2014), and *Days of Electric Sky,* which is currently also under development by Strangethink. In the future, it might be possible that the interactive cinema and the virtual worlds of the game industry will be combined, especially when the linking technology between cameras and virtual 3D modelling becomes more developed.

1.2.4 Interactive cinema

Interactive films have been considered as games, and therefore also referred to as Movie Games or VCR Games. The difference to video games is that the content is cinematic and/or using full-motion film. The interactive movie image has various possibilities to create non-linear storytelling through interaction, logarithmic rules, or customisable elements. The interaction is a function to get to the next part of the story, and this is the difference to linear film making; interactive film needs a visual and physical interface.

Interactivity between the film and the audience was first used in 1967 in a film called Kinoautomat, where the audience in the movie theatre could interact with the film's plot changes by choosing the following event in the film by pressing a button. However, every once in a while during the film, there were two given choices to continue, and no matter which one the audience selected, the outcome of the story still remained the same (Veale, 2012). This led to the first interactive motion picture "I'm your man" in 1992, where controllers were installed into the movie theatres. With the controllers, the audience could vote for the decisions of the main character. The movie was not a success, and the controllers were removed from the theatres.

The ways for the audience to interact with the film has been transforming. Lately, the keen interest has been on the emotions, and even on the brain activity of the viewers. Technology, such as the brainwave-reading MindWave headsets by NeuroSky, became available in 2010 with a MyndPlay platform, for which the UK film company Treite Labs has produced interactive movies (Neurogadget, 2011). The MindWave technology supports only one viewer per film at a time. For bigger audiences, a company called Filmtrip Ltd. is creating interactive films, Biosuite and Emotional Response Cinema, where the state of the viewer affects the story, music, and sound effects of the film. The sound design of this system could be labelled as a generative sound design, where the interface generates the sounds for the story according the audience's emotions that are electronically detected from the fingertips of the viewers (see figure 1.5). (Filmtrip, 2013.)

Figure 1.5 An interactive film with the audience having sensors on their fingers (Filmtrip, 2013).

1.3 Perceptions of sound

When we talk about audio, we normally refer to the technical properties and attributes of the actual audio file. This can be the frequency rate, bit depth or another technical property. However, when talking about sound, the concept of perception comes along and makes us talk about sound the way we hear it. This is the way that the attributes of audio and sound are distinguished from each other. Acoustics, the physics of sound, and scientific psychoacoustics will not be discussed in this thesis any further due to the irrelevancy of the scientific factors of measuring perception in experience-based listening. Therefore, the technical aspects of psychoacoustics, such as the human hearing, the speaker systems, or reflection times will not be reviewed. With the modern sound technology, it is possible that the technical quality of the sound design will already be in a media format that is as technically good as possible. Furthermore, when designing generative sound installations, the localisation and acoustics should naturally already be included in the design process.

In this thesis, I will strive to discover the complete experience of hearing and perceiving sounds in sound design. I am especially interested in the ways that sound is perceived and in its effect on the quality of the experience and the emotions. In order to find these ways, some habits of listening and methods of defining the relevant terms need to be discovered. A clear definition of perceiving sounds is: “Hearing is passive, listening is active” (Sonnenschein, 2001). I also agree that concentration is needed, since “listening begins with being silent – Joachim-Ernst Berendt” (Sonnenschein, 2001). However, while interacting, the listening mode changes somehow. There are different ways to hear or to listen either actively or passively. What we hear is always influenced by many other factors around us, such as the visuals and haptics, and by many factors inside us, such as our emotions and memories.

There are several ways of listening and psychological methods that affects what and how we hear and interpret sounds. In this chapter, I will concentrate on the psychological and emotional reasons of how people perceive sounds. Several different listening modes have been discovered, and the way people hear develops and alters constantly. The developing technology brings us new forms of focusing or defocusing attention through new ways of looking, listening and interacting (Crawford, 2009). Through these new forms people redefine the limits of what is possible and use them to evaluate the qualities of the experience.

The way we listen and associate sounds happens through our own personal sound memories and sound history. Therefore, we connect certain sounds to our emotions. Cultural backgrounds bring different sound cultures to our sound history, which is why the same emotions can have several different sounds to trigger them.

While we are listening to something, either intensively, passively, actively, or when interacting with an image, the situations of how we hear will definitely vary. However, I trust that I will be able to discover common factors in these situations and that these factors could be heard in the same way regardless of the background of the listener or the listening situation.

1.3.1 Listening modes

There are three listening modes by Chion for audio-vision, including causal listening, semantic listening, and reduced listening. These listening modes refer to the ways to detect what we hear. *Causal listening* is about listening to the cause of the sound. The sound cause may be visually seen and then it gives us more information about the object. If not seen, then the cause is based on our own sound memory (see chapter 1.3.2 about sound memory). This listening mode is acclaimed to be the most common way of listening. *Semantic listening* is part of linguistics and the way that spoken language is listened to. It also includes Morse and other code languages. It refers to what and how things are said. *Reduced listening* is identifying the sound itself and describing it. This means that in order to do reduced listening, it is required to hear the sound many times, therefore listening to a recorded sound over and over again. It is an unnatural way of listening, which is nevertheless very useful for training the ears, especially of the people in the sound industry. (Chion, 1994.)

Other listening modes have been introduced as well, such as reflexive, connotative, empathetic, functional, signal, critical, component analysis, analytic, and engaged listening. *Reflexive listening* is about how we hear through our primitive instincts and the way we react to them. *Connotative listening* refers to recognising the sound but not fully understanding what is heard, i.e., hearing foreign conversations without understanding the language. During *empathetic listening*, the listener personifies the sounds by connecting them to his/her own feelings. *Functional listening* means that we hear sounds that have a certain purpose to inform or warn us, and *signal listening* means that we are expecting this important sound event. During *critical listening*, the listener tries to figure out if the sound is right and fits the purpose it is being used for. In *component analysis,* the listener tries to dismantle the sound into pieces or parameters in order to analyse the sound structure. Finally, in the *analytic listening* mode, all of the listening modes are being utilised to reveal the deeper meaning. (Farnell, 2008.)

Gaver has also introduced two ways of listening: *musical listening* with the acoustic properties of pitch, loudness, and time; and *everyday listening*, where the listening focuses on events rather than the sounds in everyday life (Gaver, 1988).

For interactive listening, the most important listening mode is the *engaged listening*. While engaged, the listener is interacting with the sound and trying to understand the process through sound. “The sound may drive physical responses while the responses also drive the sound” (Farnell, 2008, p.101). In addition to interactive listening, there is also some research on the *listening in social media,* which discovers the way people listen online (Crawford, 2009).

These different listening modes, either several or all, may apply simultaneously while listening, not just one at a time. We also need to remember that listening happens with the mind, and there are no ways to physically shut the ears (Chion, 1994). In the same way as time and technology changes, the way we listen changes. New listening modes will surely appear; maybe even a listening mode specifically for generative sounds and sound designs.

1.3.2 Auditory memory and cultural history

Sound always triggers a memory or a past situation in the listener, even if the listener does not have a personal experience of hearing the sound before. This is based on conceptually-driven processing. The listener reflects the expectations to his personal memory of a similar situation with similar sounds, and due to this, the “expectations based on memory form the basis for understanding the significance of events” (Gaver, 1988, p.24). Past remembrances are always affected or coloured by the present. Soundscape researcher Helmi Järviluoma has named this event of identifying the heard sound and “re-experiencing a sonic event as ‘hearing-point memory’” (Schine, 2010).

In the sensory memory, a register called echoic memory, in other words, the auditory sensory memory, restores auditory information. The echoic memory stores the perceived sound, sometimes with large amounts of information. Only after receiving the following sound is the previous sound made meaningful. This echoic memory can be tested and measured by using different tasks to test participants.

A new scientific research by the researchers at the University of Iowa in 2014 states that people do not remember sounds themselves without a connection to an event, situation, gesture, smell, or visual stimulus. To be able to remember individual sounds, the time span of the auditory memory is greatly shorter than with other sensory memories. The study also proves that our memory of touch nearly equals our memory of sight, which is why these overpower the auditory memory. (Bigelow, 2014.)

The auditory memories and histories are different for everyone, and also different sounds in different cultures mean different things. While “Sound will change, it has a history” (Sterne, 2012, p.7). It may be the case that some sounds might not have any meaning in other cultures. When talking about sound, the cultural background together with knowledge creates problems in the communication. Because sound is ambiguous, the vocabulary for sound is difficult and time-consuming to learn.

For the recognition of repeating sounds to occur, there has to be a correlation with a memory or a feeling. Irritating sounds might be remembered better than pleasant sounds. Therefore, as the memory recognises the repeating and irritating sound, I believe that with generative sound design this could be avoided. I wonder whether generative sound design could affect the sound memory action in other ways as well, and whether the impact would also be emotional.

1.3.3. Emotional impact to listening

Sound has different kinds of energy forms that transact to the listener. These energy forms create an emotional impact in the listener. An emotional quality of the sound affects the interpretation of the audience’s reaction (Sonnenschein, 2001). With films, the affect of sound upon sensation and perception is uni-directional; with interactive media, it is bi-directional (Sonnenschein, 2001). The different qualities of sound affect the perception of the audience in different parallel levels, as can be seen from figure 1.6.

Level	Qualities	Perception
Physical	the mechanical, electronic, and technical aspects interacting with our bodily, biological functions	auditory system, neurological functions
Emotional	story, emotional identification with the characters and their goals, creating empathetic reactions (like laughing and crying)	laughter, tears, heartbeat, empathy
Intellectual	structural, aesthetic considerations that are most often conveyed verbally in the context of human interaction	heightened awareness, confusion, mystery, suspense, humour
Moral	ethical or spiritual perspectives and dilemmas, alerting us to possible choices beyond our own personal fulfilment or survival	choice of identification, inner questioning

Figure 1.6 Sound perception qualities. Based on sound energy transformation by Sonnenschein (Sonnenschein, 2001, p.xxii-xxiii).

Emotional sound is usually linked with memory. While storing sounds to our memory, we are also able to preserve an emotional meaning or information together with the sound. Researchers have also found a link between smells along with sound and memory (Rettner, 2010.) Not only is our daily sound memory giving us assumptions to evaluate the heard sound, but also the film industry sound design through Foley sounds (see chapter 3.2.4 about tailored sound design) has created into our memory a “notion of prototypicality” (Ekman, 2008, p.24). We have learned how a certain object or event should sound like because we have learnt it from films. These prototypes are perceived as more beautiful, and they are also easy to recognise and therefore to rely on (Ekman, 2008).

Naturally, the dialogue and the music have their own roles in the game play as in films, though with sounds the emotional effects are achieved with the volume level, timing, and source of the sound effects. It is acclaimed that the soft, quiet, sounds in the games are considered to be in the background as atmospheric and to be overpowered by the loud sounds. The loud sounds are acclaimed to be most effective sounds, and they need to be played with high volumes in order to be perceived and evoke sudden emotions. (Toprac & Abdel-Meguid, 2011.) There are three choices for the timing a sound effect: “(1) the sound effect is timed to coincide with a corresponding, often visible event or object, (2) the sound effect and the corresponding event or object lag each other, or (3) the sound effect is played without regard to corresponding specific event(s), that is untimed” (Toprac & Abdel-Meguid, 2011, p.182). The timing may result in an emotional impact, such as startlement, fear, or suspense in the player. By seeing the source of the sound effect “the threat becomes salient” and causes fear in the player; and by not seeing the sound source, and with an unclear relationship with the sound and visuals, it causes anxiety in the player (Toprac & Abdel-Meguid, 2011). Nevertheless, the emotional impact in games is more complex to achieve with sounds, not only because of the technical differences when compared to films and non-linearity, but also because the sound has multiple tasks all in real-time. The sound has to function as feedback, be responsive, immersive, and avoid repetition. It should also support the narrative, have character, and impact the emotions either positively as pleasant, or negatively as unpleasant sounds. (Ekman, 2008.) Overall, emotional impacts are closely related to immersion, and their combination results in emotional interaction (Cunningham et al., 2011). See more about immersion in chapter 3.2.2.

1.3.4 Physical and physiological responses to sound

Sound perception will also cause physical and physiological responses in the listener and the listener’s emotions. Inger Ekman, a researcher, who wrote her doctoral thesis on Game Sound Design, refers to these responses in the following way: “Affective responses include paraphernalia of bodily responses (pounding heart, sweaty palms) and may also bring with them a certain action tendency” (Ekman, 2008). According to Ekman, these responses could be labelled as the sources of our emotions. They will increase the emotional effect with a physical impact, for instance the increasing level of adrenalin, and this effect can be immediate or unconscious. Ekman also states that the emotions are short term and therefore different from moods. She also claims that through the usage of injections of adrenalin in the misattribution study by Schachter and Singer, it was proven that the context partly determines the emotional state.

There are several responses that influence sound perception, most of which originate from ferocious reactions and instincts. Procedural audio specialist Andy Farnell has listed the different responses that we have while hearing certain sounds. Based on his text, I gathered this table to point them out.

Response	Description
Stapedius reflex	The ear shuts itself to protect the ear from very loud sounds.
Startle response	A primal hearing state where a threatening sound or the sound of a possible attack is heard. This results in increased heart rate and focused attention towards the sounds.
Orientation response	A short, sharp sound off-axis that will make the head turn in order to see the sound source for identification.

Response	Description
Ecstatic response	Hearing a particular sound with an emotional charge results in a sensation of shivers and goose pumps.
Stress response	When hearing exiting and powerful sounds with intense sound pressure, or an unwanted sound, the effect is raised blood pressure, sweating and raising adrenalin level. May also be referred to as sound torture.
Binaural beat entertainment	The long-term listening of two different, pure tone sounds in each ear has effects on mood, and it stimulates neural activity in the brain.
Psycho-therapeutical applications and art	The usage of sounds and music as therapeutical strategies. The goal is to use sound to affect emotional change.
Cross-modal perception	Discoveries of sound influencing the perception of another field (moving objects in the visual field enhance auditory perception and vice versa, connections between sound and touch, where feeling can be influenced with sound, and sound vibrations can influence the perception of loudness).

Figure 1.7 The physiological responses (Farnell, 2008, p.99-101).

Also a sound designer may think of the image or imagery that the sounds will create. The aim is to create an image with the sound. I have also heard some saying that they are painting with sound. For instance, the sounds of the beach will create an image of the beach to the listener. This is an effect where the listener will see the beach even while only hearing it. This kind of an event refers to “seeing” the sound, even though no visual stimulus toward the sound is provided. Some people can also see sounds as colours. (Sonnenschein, 2001.)

2. Generative sound design

Generative sound design is a method of sound design that utilises the possibilities of the diversity of various sounds and sound textures in creating sound design entities for different purposes. These entities can applied to video games, mobile applications, sound art or installations, interactive films, web pages, or even products. Generative sound design requires programming and an interface to run or generate the sounds within the media. Several of these interfaces and setups have been created through the development of generative music, and they have led the way for generative sound design.

Generative sound design has its origins in generative art and generative music. It is challenging to try to categorise generative sound design, as it is both art and design simultaneously. It can also be interactive or not interactive. Depending on the interactivity, it can be included as part of the sonic design or sonic interaction design (see figure 2.1). It is also problematic to define when a sound design becomes generative, which is why I have gathered the methods of building generative sound design to this chapter. Since these methods are quite mathematic and technical, they require the knowledge and usage of audio programming languages and audio engines, which will be introduced in this chapter as well. Because interactivity is an important part of generative sound design, an interactive system in a generative sound design is also presented.

The generativity is closely related to non-linearity, which makes the design process different from designing sounds for film and radio. Nowadays, sound design is in a state of transition, and this non-linearity and the methods of generative sound design have become the trends of today. Therefore, generative sound design can be thought of as a new process of handling audio in new media formats. I consider this as an emerging way of handling sound. However, as Sterne (2012) states, “New processes for manipulating, transforming and working with sound come and go in the space of decades” (Sterne, 2012, p.1). While the benefits of generative sound design still require justification, it will remain to be seen whether generative sound design is here to stay, or whether it will develop into something else, or create something entirely new.

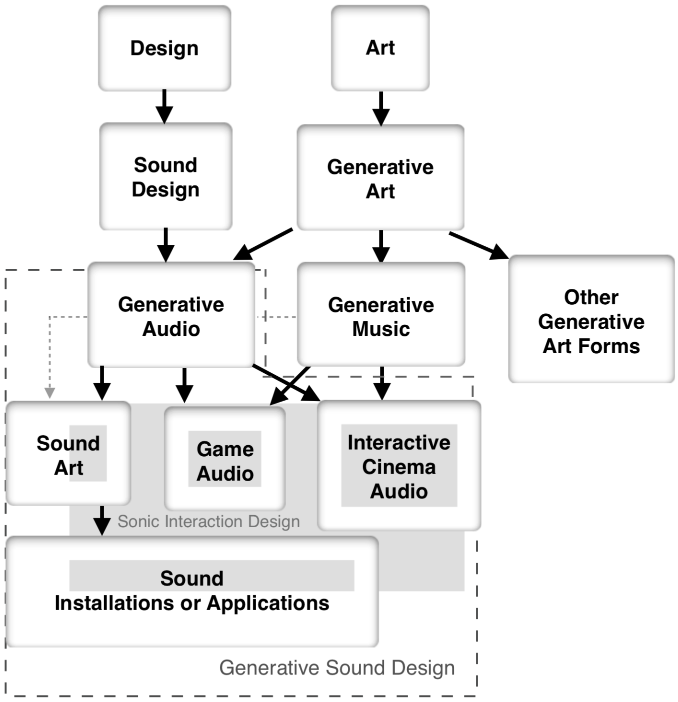

Figure 2.1 Generative sound design structure.

2.1 Terminology

Generative as a term refers to having the power or function of generating, originating, producing, or reproducing. Generative also implies creating something new, such as the ability to produce new life or even to be fruitful and multiply (Farlex, 2014). Therefore generative sound design could also be called *productive sound design*. Game sound designer Paul Weir (2015), who is specialised in generative audio, calls generative sound design “never-ending audio”. I would call it “always changing”, because generative sound aims to avoid repetition, and generative sounds may occur for an undefined period of time, though not necessarily infinitely.

The people in the sound design industry still define the term generative sound design quite differently. The word generative is a term that has mainly been used with music, since generative music is more widely and commonly known. Also the term emergence, which indicates the process of emerging and outgrowing, is often combined with generative art forms. In generative music, it is more commonly used as a sound structure. Composer John Cage has said that he considers “music as the production of sounds”, whereas composer Edgard Varèse created “organised sound” instead of music (Priestley, 2014). Still, the difference from generative music is not quite clear, and as Priestley states: “all sound is potentially music, depending on one’s mode of listening” (Priestley, 2014). The line between generative music and generative sound can therefore be vague and hard to distinguish.

Something that is generative is immediately thought to be made with computers and algorithms. According to many, the generative action happens randomly, or on the fly, and it is mainly thought of as being executed and generated by a computer. Although it is executed by a computer, the rules for the actions are set by the creator of the generative sound design. Therefore the generative process is always under the control of a human action. Each work needs a sound design plan and rules for an execution, even though it is run by a computer independently.

2.2 Generative action

What really is a generative action is something that is still being debated. There are many interpretations on the matter, and it is hard to denote the thin line when the action becomes generative or not. It has also been hard to distinguish where the control of the generative action is lost with the computer, or whether it has been lost at all.

To me, the design becomes generative, when the reproduced sound is manipulated by the computer in any way that creates an unpredictable outcome of the sound, or when the system simply generates a new sound unpredictably. This also includes the way that the sounds are played, even if the sound texture itself is not manipulated, but instead the computer decides when the sound is to be played. "A generative sound model is an algorithm for synthesising a class of sounds under parameterised control, typically in real time" (Wyse, 2005, p.1). The control of the generative design can be on the hands of the creator or the computer, although this is something that the creator has to program the computer to do. The sound generating system is not able to directly cause any change or adjustment in the 'external conditions' set to its own process by itself, i.e. it has no active part in determining the control data needed for its changes of internal state to take place (Di Scipio, 2003). Ultimately, the sound designer is in control of all of the behaviour of the computer. Still, the generative sound design is always ran by a software, and it is something that continues to run without the help of the creator on its own, as a standalone, meaning that it is not a live performance of the creator but of the computer.

It is also unclear whether the generative sound itself is interactive. If the computer generates a sound, will the impact of the listener modify that sound or not? I personally think that the sound can be generated by the computer and also be modified by the listener at the same time. I would therefore slightly disagree with Andy Farnell's thoughts about generative sound, as he states that "The definition is often given that a generative piece requires no input, or the input is given only as initial conditions prior to execution. Analysing many practical implementations this definition breaks down, but if we stick to it strictly then generative sound is not interactive." (Farnell, 2007, p.3.) What if the listener cannot predict what the texture of the sound is, but the impact obviously makes some kind of modification to the sound while the computer is generating the sound? This modification can be for example something related to the pitch or length of the sound, or something to momentarily (only during interaction) diffuse the sound in some ways. Nevertheless, the sound plays generatively, even if there is no impact or interaction by the listener.

2.3 Generative sound design process methods

A generative sound design process may utilise many features of designing sounds to make them different and changing all the time. It may use both samples of sounds and completely digitised sounds created from scratch. In this chapter, I will go through all the forms of sound design that the generative sound design can consist of. The process of generative sound design can be executed either with one or several of these sound design methods.

The generative design process in figure 2.2 shows a designer’s process of creating a generative system. This is directly applicable to the sound design process, such as the model created by Lonce Wyse (2005), and based on his conceptual components of a sound model (p.2) and the model in figure 2.2; I created a model that fits the generative sound design process. This model works with or without the Interactivity/Action part. The generative sound design process model consists of the components presented in figure 2.3.

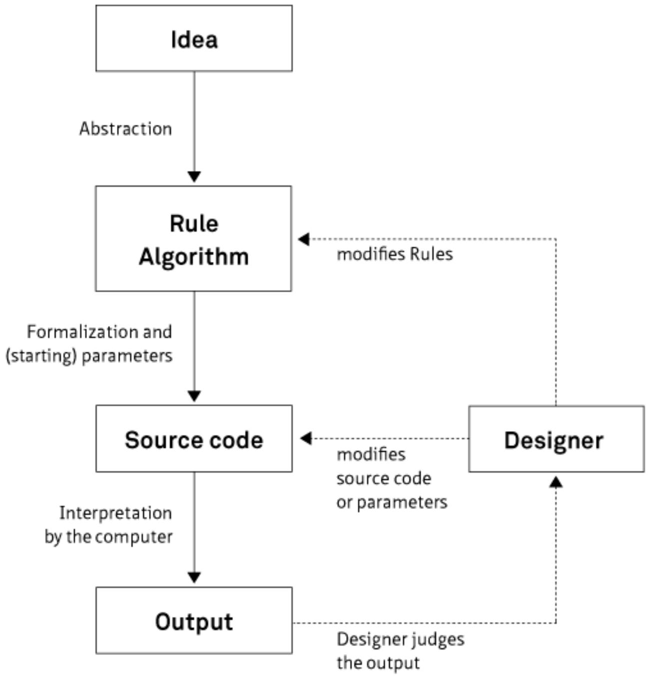

Figure 2.2 Generative design process (Bohnacker et al., 2009).

The computation part, or synthesis, could be referred to as the motor for the generative sound design. There are several techniques to implement the system. “A wide array of techniques have been developed for real-time sound synthesis, from the playback of segments of prerecorded audio to the calculation of the oscillations of complex physical systems in real time” (Visell et al., 2013, p.88). These can be created with the help of algorithms, artificial intelligence, and other rule-based processes. They can be created with audio programming languages or generative sound systems, such as the game audio engines.

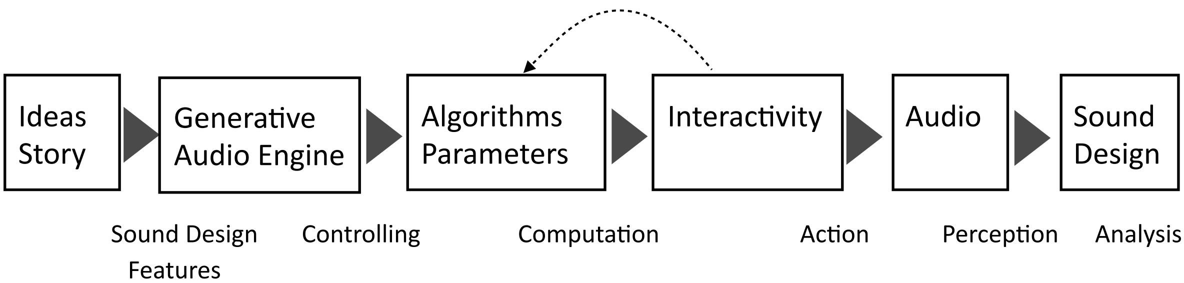

Figure 2.3 Generative sound design process model. Based on the conceptual components of a sound model (Wyse, 2005, p.2).

2.3.1 Adaptive audio

The designation adaptive audio was established along with the development of game audio engines, where the audio can be set to follow the actions of the player and therefore varies. Adaptive audio is commonly used in video games and also in multimedia platforms and applications. It is also mostly referred to function as feedback information of the player’s actions, and it uses pre-recorded sample sounds. Adaptive audio is also known as interactive audio that has a real-time connection with the screen action (Lapington, 2006). This connection can be also called “…an elaborate relationship between the user input and audio output… It is a form of interactive sound where a complex function or state machine lies between the players actions and the audible response.” (Farnell, 2007, p.2.) In my opinion, adaptive audio is interactive audio, whilst not synonymic. The sound adapts to the visual response given to the player and functions as an audio feedback. Therefore it can be assumed that adaptive audio always requires a leading interaction or visual stimuli, whereby it winds up in a supporting role.

Because the adaptive audio is based on playing a sample sound according to interaction, I would agree with Paul Weir that adaptive audio is not really creating something new and it is like live-mixing (Weir, 2014), because the sound is played according to a certain interaction the same way every time. If sound modulation is added to adaptive sound, it is possible to manipulate an uploaded sample sound in the audio engine: the system generates a new sound, for example, by changing the pitch or texture of the uploaded sound sample. This means the adaptive sound becomes generated by the audio engine. Since the engine generates new sounds, the audio engine becomes generative. These systems can also include procedural audio plug-ins to create completely new sounds without pre-recorded data (see the description of procedural audio in chapter 2.3.3). The more complex the creating process and the randomness of the sounds within the system, the more it develops towards the generative sound design. The complexity can be added with rules or algorithms in order to manipulate the sound.

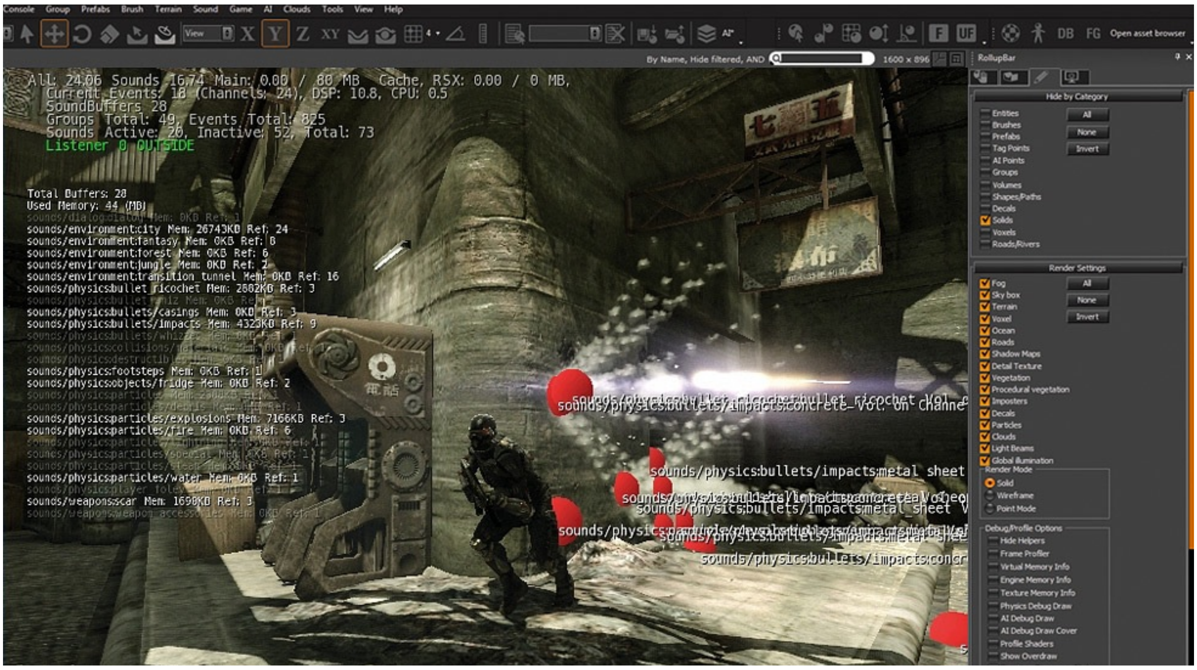

Figure 2.4 Adaptive audio implemented in a game environment (CryEngine3) (CryEngine, 2013).

2.3.2 Algorithmic, stochastic, rule-based, and artificial intelligence (AI) sound

An *algorithmic process* is based on mathematic rules and methods, although the process in generativeness is not interested in the solution, but the actual passage of it. “One class of generative sounds are known as the mathematical methods which concern finding sequences with useful musical properties by iterative methods. This is actually a serious subversion of the common understanding of the word algorithm.” (Farnell, 2007, p.4.) As a result, during the generative process of these iterative methods, the algorithm is needed to repeat or keep running eternally. A classic example of such an algorithmic process is the Markov Chain, where the randomness happens through states; the latest state determines the next state that will happen (see figure 2.5). (Farnell, 2007.)

More specifically, there are three different methodologies for algorithmic composition: stochastic, rule-based, and artificial intelligence (AI) based composition. The stochastic is built around randomness or the probability of chance, the rule-based is following a language built with rules once initiated, and the artificial intelligence follows but makes its own decisions about how to use the functions. (Larsen, 2008.)

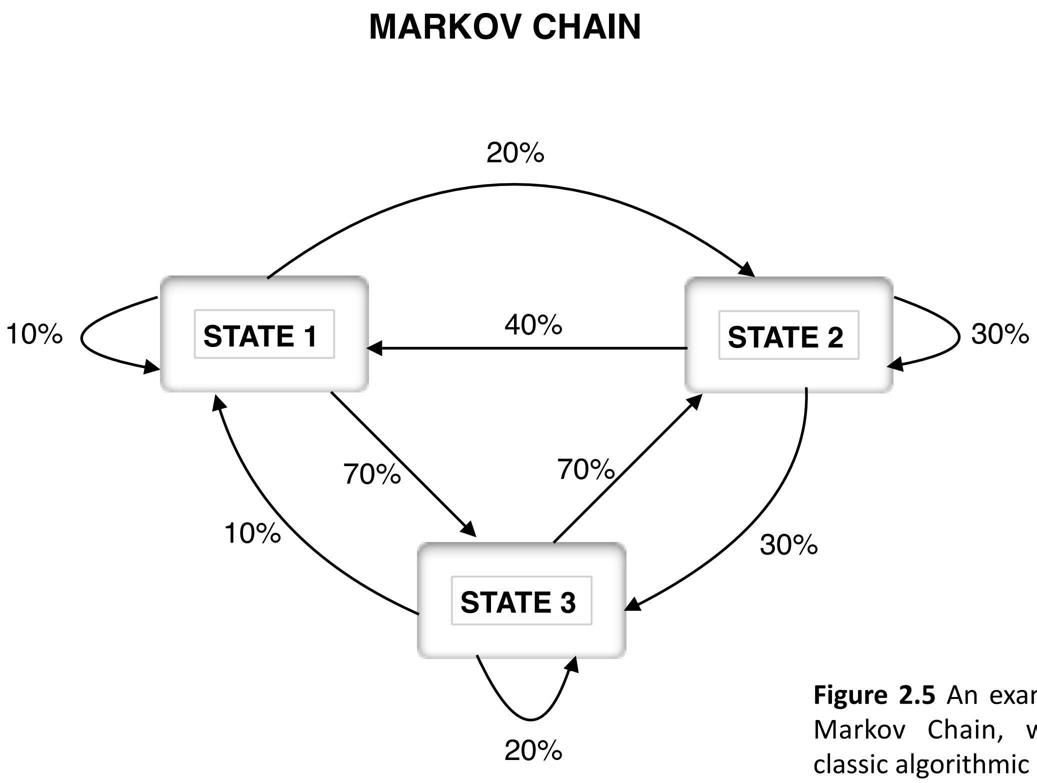

Figure 2.5 An example of the Markov Chain, which is a classic algorithmic process.

A stochastic system generates sound through random or chaotic data. This data can be formed with algorithms or with complex set of rules. Stochastic sound can also be generative or interactive when controlled by parameters (Farnell, 2007.)

A *rule-based system* can have several rules written in one or more languages. The system will follow the rules accordingly. Audio rules can follow rules from other software or rule each other by sending Open Sound Control (OSC), which is a protocol for networking for sound between synthesizers, computers, and other multimedia devices.

An *artificial Intelligence (AI) sound* is created with a set of highly complex sequences of algorithmic methods. During these methods, the system stores variables into memory, maintains its state and evaluates continuously incoming input (Farnell, 2007). With AI programming, everything seems possible, since a new creative and generative AI has been invented; a software which creates new software (Moss, 2015).

2.3.3 Procedural audio

Procedural audio designates a sound created with digital data only. It is created with signal processing and digital synthesis. A procedural sound is mainly a synthetic sound. The synthetic sound only forms from equations and functions and no other data. The sound can emulate real instruments, nature sounds and ambiences. (Farnell, 2007.) It is basically a physical modelling of a sound, for instance, creating the sound of the wind with synthesis, where the sound is not based on a recorded audio. Procedural audio is also often thought of as a generative sound or meaning the same. I would say procedural audio is a part of generative sound design; it can be one of the elements in the sound design work as well as generative music, or AI sound, or any other form of producing sound.

In figures 2.6 and 2.7, the differences can be seen between a commercial and an open source platform for a procedural sound plug-in/engine. The AudioWind plug-in is more user-friendly than the PureData wind generator that needs to be built with programming by the sound designer before being able to create the wind sounds. The Audio Weather, created by AudioGaming, which simulates weather effects, is the world's first commercial procedural audio plug-in.

Figure 2.6 The procedural wind plug-in in Audio Weather PRO Bundle (AudioGaming, 2015).

It has been acclaimed that the procedural audio is still quite detectable from the recorded audio, because the technology in procedural audio does not provide the aesthetic quality like the actual recorded sound (see more about aesthetic quality in chapters 3.3.2 Assessing sound design quality and 3.3.5 Procedural sound vs. recorded sound). While lacking the aesthetics of recorded audio, the procedural audio is still mainly used for the background sounds, atmospheric and music, and interactive procedural audio has not been implemented in audio engines as much.

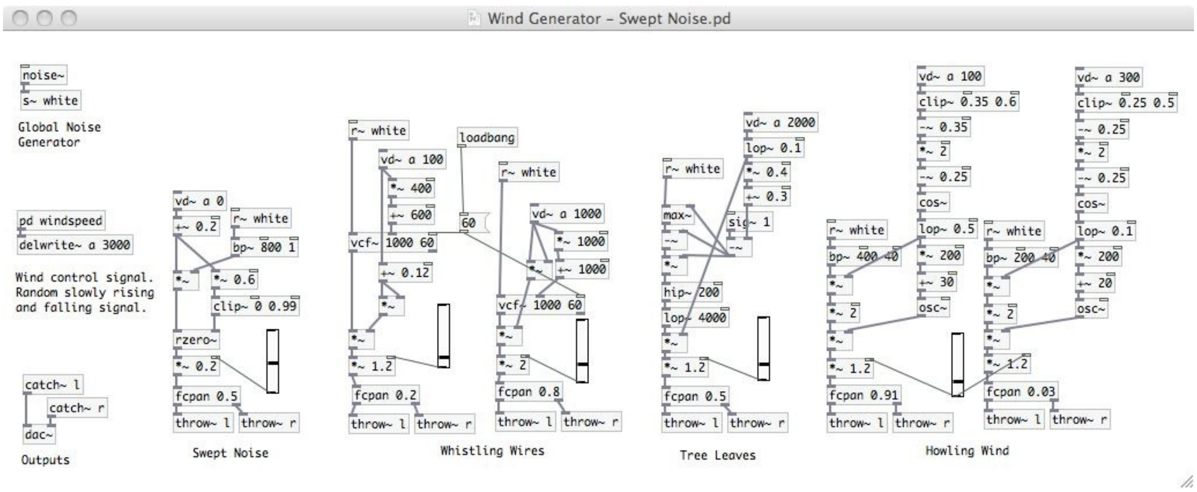

Figure 2.7 A wind generator in PureData based on Andy Farnell in Designing Sound (Meachem, 2012).

2.4 Generative and interactive sound systems

In sonic interaction design (SID) sound is an active medium "that can enable novel phenomenological and social experiences with and through interactive technology" (Franinovic et al., 2013, p.vii). There are several ways of experiencing the sonic interaction, although, the triggering factor in an interactive system can be only a presence or a gesture. According to Chris Crawform, interaction is "An iterative process of listening, thinking and speaking between two or more actors" (Gibbs, 2007, p.102). In his statement, the listening is the input, thinking the processing, and speaking the output (Gibbs, 2007). Any source can be used as the input, if it provides clear information. The source can be a camera, a microphone, a sensor, or any input device. This information will then be processed in a physical interface. With the input values, the output/feedback can be sonically altered.

When a generative sound design becomes interactive, a continuous interaction design is often needed (Franinovic et al., 2013). However, even though sound is attached to time, "There is no interaction with sound without time" (Franinovic et al., 2013, p.61), the generative sound design can fool time either with clever rules or with unpredictable and always changing methods. Then the experience of the user or the listener becomes a time forgetting event; it creates a harmony between the user and the system. "Successful technologies are those that are in harmony with users' needs. They must support relationships and activities that enrich the users' experiences." (Shneiderman, 2002, p.2.) Therefore, I would call the generative system an enriching experience, which adds a beneficial value to the interactivity and the user experience.

In order to demonstrate this generative and interactive system and the relation of it to the user, I created the figure 2.8 based on the human-machine interaction loop by Visell et al. (2013). The interaction between the user and the computer is attached to time in the system: the time to interact and to give the input, and to get the audio output as a feedback. The interactive audio loops can be infinite; the sound may or may not continue without the interaction. The interactive audio loop also affects the quality, which is also evaluated along with the interaction. This generative system loop can be created with audio programming languages and game audio engines.

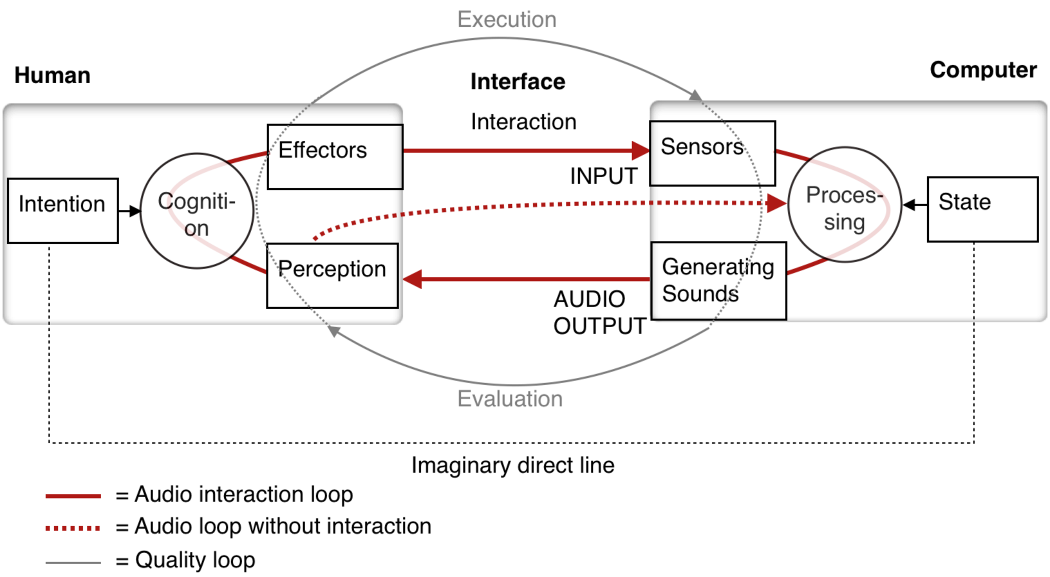

Figure 2.8 An audio-tactile interaction loop. Based on the human-machine interaction loop by (Visell et al., 2013, p. 86).

2.4.1 Audio programming languages

There are different tools to control and manipulate the sound behaviour in order to create generative sound design with audio interaction loops. The generative game audio engines are mostly used with games, but they can also be easily attached to a sound installation or mobile applications. With sound programming languages, it is also possible to design and build your own generative sound software for specific purposes. All these engines are based on their own individual rules of working. To create these rules, the sound designer is required to learn a specific programming language and the engine interface in which the creation of the system can be done.

PureData is an open source programming language based on visual, data flow programming. Algorithms are presented as objects and these objects create patches that can then be transformed into created applications of their own. PureData is free to download and to use. (PureData, 2014.)

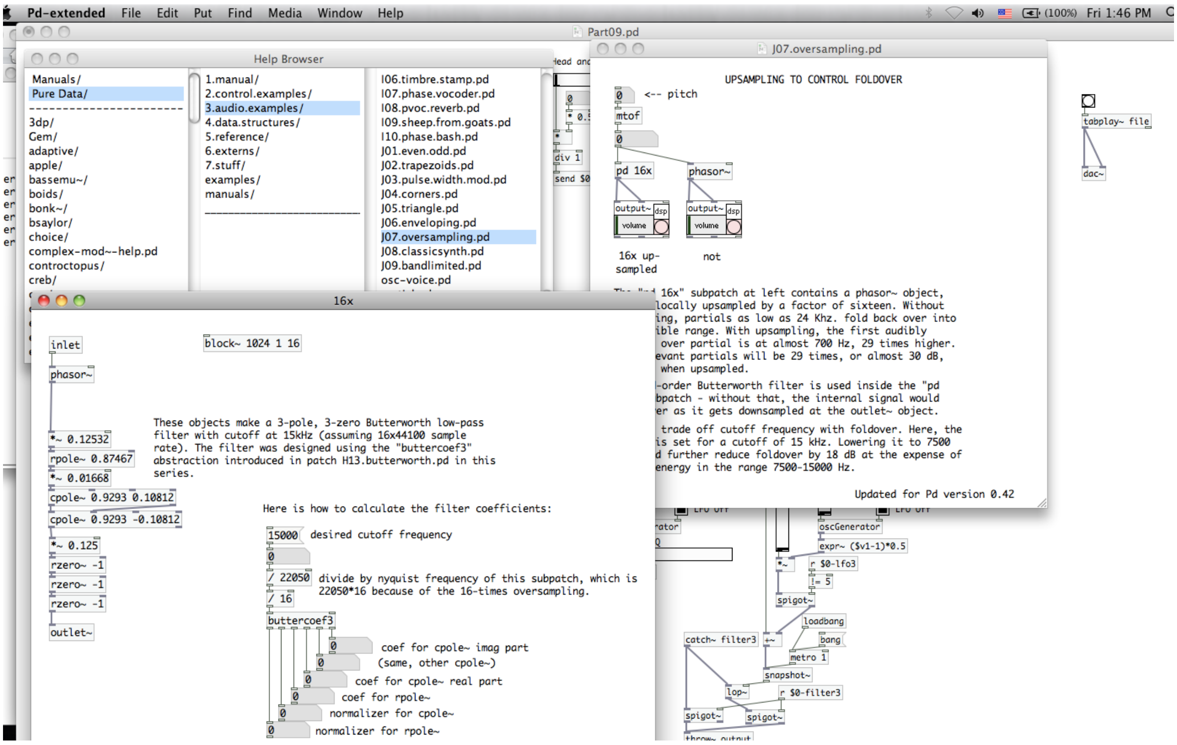

Figure 2.9 Object programming in PureData (PD-Extended) (Farley, 2013).

Max/MSP is also based on visual programming with the same methods as PureData. Max was developed for music and multimedia, especially for interactive music/video performance. (MAX/MSP, 2014.) The difference to PureData is that Max is not an open source based software, and it costs around 400 dollars.

Impromptu is an interactive live coding environment based on OSX programming. It is designed for sound designers, composers, VJs, and graphic designers and artists. It is accurate when scheduling real-time events and therefore designed for live running software. (Impromptu, 2015.)

Csound is based on the C language and an audio programming language for sound, also know as audio DSL. It is a sound and music computing system, which is also used for interactive purposes, and it is free to use and download. The language can also be combined with other programming languages. (Csound, 2015.)

Supercollider is a real time programming language for audio synthesis and algorithmic composition. Unlike PureData or Max/MSP, Supercollider is not based on visual programming. The specific script language has to be learned in order to program with the engine. However, the script does resemble the C language a little. Supercollider is an open source software and can be downloaded and used for free. (Supercollider, 2014.)

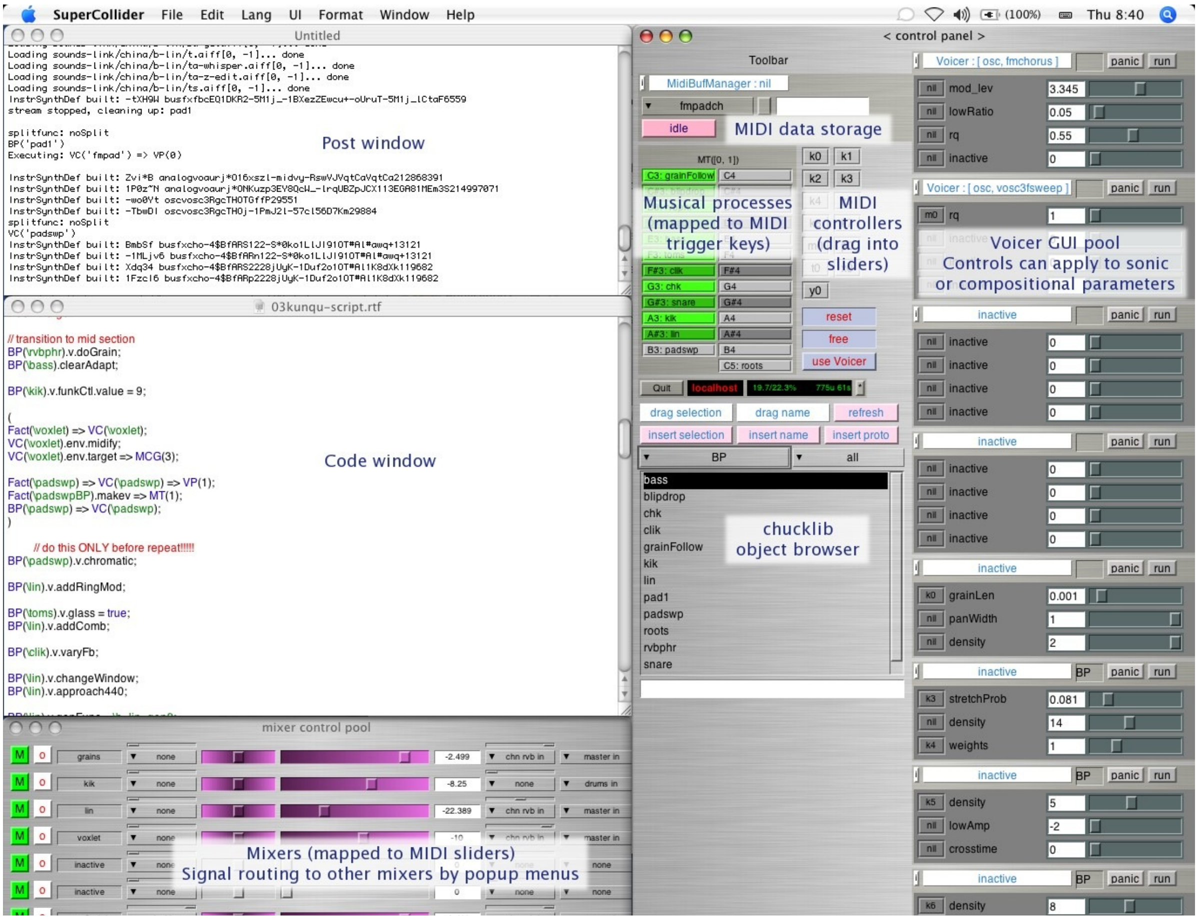

Figure 2.10 An example of programming in Supercollider (SuperCollider, 2015).

Other programming languages supporting signal processing and synthesis with algorithmic features are MATLAB, Koan, Noatikl, and Nodal. All of these engines mentioned above are being used by artists and researchers who are working with interactive sound or music. With them, it is possible to create generative sound software. The controlling of the sound happens through the Open Sound Control (OSC), which is a protocol for communication between sound synthesisers, computers and multimedia devices.

There are also other generative systems, which are trying to become known generative software. However, it seems that these systems are being sold to companies, and the software is not available for free in an open source. One of them is the *Ambifier*. The developing company called The Sound Agency is selling it on its website by stating: “The Ambifier is the world’s first commercial generative sound system” (The Sound Agency, 2014). Also mobile applications have plenty of generative audio apps that are being sold or created for different mobile devices. Most of them are based on playing generative music, and many are created by Brian Eno.

2.4.2 Game audio engines

Figure 2.11 A sound project in FMOD Studio.

The *FMOD Studio* software is the visual controller of a game sound engine. FMOD refers to itself as “an adaptive audio workstation and engine for games” (FMOD, 2015). FMOD is claimed to be user-friendly with its graphical interface, as it is designed to be like a digital audio workstation. The FMOD software is designed for sound designers to easily see and hear their sound design for the game with the help of the software without the need of having to program everything. Nonetheless, the help of a programmer is needed in order to get the functions within the software to work with the game engine and the overall created rendered files to work within the game. I believe that to many sound designers FMOD is easy to use and light to package, which is why it is possible to connect to a mobile game. Also the *UNITY* game development platform for creating games is based on a FMOD audio engine and supports the integration to FMOD studio.

Figure 2.12 A game sound project in WWISE (Stahie, 2013).

Wwise by Audiokinetic is based on the same idea as FMOD Studio. It is very similar, but the writing code uses an integrated development environment and therefore contains more possibilities of tweaking and manipulating the sound. Wwise has been most widely used within the game industry because of its many complex features of manipulating and interacting with sound. It is most popularly used in console games. The software contains 14 available platforms to publish your content. However, the system can also be used in sound installations or together with any self-programmable software or application. Wwise has many built-in effects and plug-ins that enable the manipulation of the texture of the sounds. It also contains some procedural plug-ins, for instance to create wind. Wwise is a free software, as is also FMOD studio, but if used with a published game, licence payment is needed. The amount depends on who the publisher is, and to which platform the game is being released.

These are the most used game audio engines in the game industry. Although, “Some large game developer studios may also develop their own in-house audio tech” (Hajba, 2015). This is only a matter of resources, time and money, and the compatibilities of combining the programming with the audio engine.

2.5 Potentials of generative sound design

There are many potential ways to use generative sound design. Mostly generative sound design has been used in interactive installations or in sensate environments with visual arts. There is also a growing need for generative sound outside the arts field. Some very useful benefits have been listed by Kirsty Beilharz (2004). She says that responsive sound design (see chapter 3.2.1) could be utilised in open, shared, or social spaces and foyers. Real-time music and sound generativity could be used in electronic games and the interactive entertainment industry, because they are beneficial for their real-time customisation. Generative sound content is also needed in virtual environments for design, education and social purposes.

Beilharz also wonders what could be done with the huge amounts of data that the new sensoring technologies provide. When creating interactive systems, new possibilities can arise from the complex information provided by the sensors. She thinks that the sensor data should be used and utilised somehow. (Beilharz, 2004.) This is exactly what is happening at the moment. The generative systems are being innovated in new ways in order to be utilised and also gradually commercialised. Designers are trying out different data environments, where they can transform the data into sound somehow. Unfortunately, all data does not necessarily turn into a generative process.

Lonce Wyse ponders whether the film and television industry could utilise generative processes, i.e. if Foley sounds could be done with a set of sound models in a “desktop environment” (Wyse, 2005, p.1). He disregards this by saying that the tools for this do not exist for sound designers because of limited “access to arbitrary sound control”, and that the “audio will remain a technique of clever patterns of triggering prerecorded audio” (Wyce, 2005 p.1-2). However, the tools for sound modelling have already been invented within the game audio engines, such as the Wwise and FMOD, where the sample sound will create new sounds with the alternation of pitch, length, and parameters. Also some procedural features have been encountered in software for creating graphics that could be utilised in the television and film industry; for instance to create big masses of similar objects, people, or structures. Hopefully, with generative sound, the possibilities to fit the use of the film industry can be found. It surely is an idea to take further.

I believe that there is potential for generative sound design in every product design that aims for entertainment, play, or amusement. Even everyday household items are aiming for quality usage or user-friendliness with sound. Also electric cars are being built with sound, and the sound varies according to the way the car is used. Actually, it does not matter what the product, material, or space/environment it is. With today’s sensor technology and the way it is developing, it is possible to turn almost everything into parameters and therefore into sound somehow. However, a generative process always requires computerisation, but this is hardly a problem, as computers and circuit boards are being developed smaller continuously in order to fit and to be implemented into or onto products.

2.6 Discussion about generative sound design

I interviewed eleven specialists involved with sound design and music in the field of films, games, and sound art. The interview concentrated on how they understand generativity, complexity, realness, and quality when it comes to sound and sound design.

Generative sound design was mostly understood by the interviewed professionals as something generated by the computers and with algorithms. Only one of the interviewed had not heard the term generative sound design at all, one said that purely generative design does not exist, and many thought that generative sound design would form of only synthetic sounds, or that it would be completely procedural. "Like real time synthesis of sounds. Like algorithmic music, like creating sounds on the fly. This means creating sounds for games and maybe for sound art, sound installations." (Görne, 2014.) There was some confusion whether generative sound design equals to procedural sound design, and also generative as a term was easily combined with music. "The sounding result, whether it be music or sound effects, are generated procedurally, meaning there's a procedure, or algorithm behind the sounding world. I consider it the ultimate possibility to abstract sound and music. Personally I'm mostly interested in generative music design, considering the generative sound design as the procedural sound design." (Nispen, 2014.) The confusion is very understandable, as the procedural is a part of generative sound design, and the line between these two is quite vague, as game sound designer Peter Hajba states. "There is a bit of overlap between the terms procedural and generative. Also, where does the line go from a static sound to a procedural one? From a single sound, you may go to a sound that has a few random variations of itself. This is slightly more dynamic than a single sound. Then the sound may have a few adjustable parameters, for example adjusting a collision sound based on how hard the impact is. Or we can have a racing car engine sound, that consists of multiple layers and multiple parameters, such as RPM, engine load, transmission speed and supercharger speed and pressure, all of which modify and affect the sound." (Hajba, 2015.)

It was very clear to everyone that games can utilise the generative sound design, while the film industry has not found a way to utilise generative audio. However, some speculations about games and films possibly unifying in the future have already arisen, as sound designer Elias Struck predicts. "It will be an evolution between movies and games. It is much more interesting to watch the movie while taking part. Maybe in the future you would produce a movie and a game at the same time." (Struck, 2014.) Many of the interviewed said that generative sound design is not being utilised enough. According to game sound designer Joonas Turner (2014), not even the indie games are using enough generative sound design, even though they would benefit from it much more, and the smaller games are even lacking in the basic sound design: they might not have any design.

Even though generative sound design does have some minor disadvantages, such as the lack of resources, e.g. budget, and maybe some technical restrictions with power, the overwhelming benefits were obvious to everyone. "Important benefits are the possibilities of fast responding interactivity, infinite variations in an infinite timespan, while potentially using limited resources in regard to data storage and computer memory" (Nispen, 2014). The generative sound design was thought of as a way of continuous change; the sound outcome would never be the same. "Of course it has benefits; you never listen to the same thing twice" (Struck, 2014). The system behind the generative sound design was said to be a flexible and efficient way to manipulate sounds. "Generative and procedural sound is more expressive, can respond to the game state changes more immediately, and can produce more variation without additional content, which can save memory. The disadvantage is that it will require more processing power. This is a common tradeoff - the content either requires a lot of memory, or a lot processing." (Hajba, 2015.) However, some said that generative sound design does not have any disadvantages. According to the answers of the professionals about the advantages and disadvantages of generative sound design, I gathered the following table (see figure 2.13).

Advantages	Disadvantages	Perception / expectations
Infinite variation	Not necessarily robust, or technical problems	People will not notice or realise what they hear is generative
More expressive	Requires more processing power	Players expect it already, because it sounds more 'real'
Fast responsiveness	Bigger budget	Some say it is the future, some say it kills the sound design
Saves memory if procedural	Time consuming	Thought of as easy and cheaper to do than traditional sound design
Randomisation	Complex to realise	Considered as avant-garde
More interesting	Requires programming know-how	Will find its way to being utilised
Sound behaves more realistically	Loosing control of the design	Potentials not used enough yet
Enhances the experience		Has created interest towards it
More possibilities in creativity		
Not repetitive		
Stronger immersion		
Sounds more believable		

Figure 2.13 The advantages, disadvantages and perceptions of, and expectations towards generative sound design stated by the interviewed professionals.

The only confusing issues, which varied the most among the interviewed, were: when does a sound become generative, and what is a generative action. It was not quite obvious, because to some, samples were not considered as a part of the generative process. However, the majority stated that the control is always in the hands of the sound designer and not the computer. Even if the computer generates the sounds randomly, the control is never really lost. Parameters and algorithms were mentioned, although, I believe it was not quite realised by some, what these really meant as processes to the sound outcome in practise. Nevertheless, the majority agreed that a generative action was born, when an algorithm was involved in the design. James Andean said that playing samples on as triggered without any modification was basically cheating, even if the sound outcome was different all the time. Some also said that any system is a generative as long as computers always generate the sound.

2.7 Conclusions

It is obvious that sound is meant to evoke feelings in the listener, and by acknowledging the ways the sounds are perceived in the different platforms, it is possible to alter the perception to fit the purpose of the design. To understand the process of generative sound design, it is important to know what the role and behaviour of the sound in the platform is, and how the sound is emotionally perceived.

It is proven that sound has a powerful emotional impact on the listener. All these emotions are revoked from the memories of the listener, and depending on the personal memories, culture, and history, the sound is interpreted differently. Sound always has a personal history in our memory. Therefore, through memories, we are able to connect a certain feeling to a certain sound. Despite this, it is possible to distinguish similarities in perception, because the majority of the sound memories are similar, and with the sound design, we are able to evoke the same feeling in multiple persons.

Although music and sound together form the generative audio, and the limits of sound and music are quite vague, the role of generative sound itself has started to take a bigger role in the designs. The experience is different depending on the way people perceive and listen to the sounds. Which listening mode is the best for the generative sound design depends on the design's interactivity and on the other aspects of the design. The experience is affected by how we remember and pay attention to the events with sounds. Maybe a new listening mode will appear for listening to generative sound designs with the thought of repetitive recognition, even though the key aspect of generative sound design is to avoid it.

Overall, the generative sound process requires a platform with a system, where it can offer real-time experience including sound output variety with or without interactivity. Sound generation always includes a constantly, or with an action, changing sound world, and especially in games, the feel of real life sound behaviour. With randomisation, the surprise elements can be created easily, and the interest of the listener awakened. Generative sound design has been called 'never ending' and 'always changing' sound design.

Technically, a generative sound design can be created within an audio engine according to the rules based on one or several of the following design methods. Each of the generative sound design methods functions differently. This is why I gathered a table of their behaviour in figure 2.14. With the design methods, the actual generative sound design processing can be made with a chosen technology, and by using one of the several different program languages or engines. An interactive version always requires an input affecting the sound design.

Sound Method	Random	Interactive	Not Interactive	Sample sound	Digital sound	Rule based
Sequenced		X		X		
Synthetic		X	X		X	
Adaptive	X	X		X		X
Algorithmic		X	X	X	X	X
Stochastic	X		X	X	X	
Rule-based		X	X	X	X	X
AI	(X)	X	X	X	X	X
Procedural			X		X	X

Figure 2.14 A generative sound design can consist of one or many sound methods.

The game industry, open (public) spaces, and virtual environments for design, education and social purposes would benefit from generative sound design the most. The generative sound design is gradually making its way to be commercialised, although the benefits require justification. The advantages, such as the enhancement of the experience, are clearly bigger than the technical power and financial disadvantages. Generative sound design is finding its way to be taken seriously as an important commercial value to enhance the experience; it will definitely lead the way to a future of sound design full of new creative possibilities and opportunities.

3. Generative sound design process attributes

I am examining the aspects of sound design through the attributes of complexity, realness and quality. I have noticed that these three terms provide a comprehensive aspect to the process of generative sound design. Even though I would include the terms complexity and realness within the quality, I decided to keep them separate in order to emphasise the different tasks required for designing generative sound.

The sound design complexity can be interpreted in many ways, though the core of a generative system is always the design complex. The complexity to me, while creating a generative sound design, has consisted of the complex programming and its rules, the amounts of generated sounds with manipulation of sound variations and sound textures, and also of the complex ways to avoid repetition, which is the core of generative sound design.

The sound design realness introduces the terms of organic sounds and the benefits of these tailored sound effects. Immersion with sound creates the feeling of being involved with something so intensively that it becomes real to the listener. Defining realness became an exploration of whether this illusion with sound could be created with procedural sounds or pre-recorded samples of sound, and whether a generative sound design would feel more natural, 'real', as an experience.

The sound design quality affects the entire experience through different norms, which I am exploring, along with its effect to visual quality and to the interactive experience. The sound implementation and sound functions are also crucial quality features of the design. I am trying to find out whether the sounds that have no idea or design behind them could turn into a quality sound design.

3.1 Sound design complexity

The complexity in a sound design can consist of many different tasks and features. My exploration of complexity includes the main features of generative sound design, such as sound textures, variations, and layers. These features handle the quantities of sound in different ways. Somehow, the manipulation and modification of the sounds within their context groups is involved, and the behaviour of the sound has a role while playing them. I would say that the complexity needs to be designed, while the sound behaviour and the outcome require systematic thinking and a vision of the course of events. Complexity can be associated with the system, the sound design, and the sound itself.

Overall, the complexity could be the shape and behaviour of the sound. The way that the sound is being modified with generative actions is complex: the generative rules shape and move the sound with or without interaction.

3.1.1 Terminology

Complexity as a term is easy to associate with the technical qualities of the sound, it implies to the outcome of the sound properties. It seems that quantity is a part of it, as the more sounds, the more complex the outcome is. Complexity can also refer to the parameters of the sound and their manipulation. While the sound has complex properties and the perceiving can be complex, complexity could also be thought of as a way of handling the sounds.

I would also call generative sound design a *metadesign*; the design of design (Chagas, 2006). This makes the designing process complex. The complexity requires more intelligent work behind the design; by understanding the context and narrative, the sound gains a meaning and purpose. Complexity in the design is usually said to be a positive outcome. However, if the complexity is too heavy, the result may be messy. Therefore, something that sounds great and simple may require a lot of pre-work, designing, and processing with complex methods. Also the actual execution may be very complex when using mathematics, algorithms, software compiling, and technical solutions.

Also the sound itself can be considered as complex; the sound texture can be heard as a complex sound event. Therefore, the term complexity can also refer to the sound characteristics. This of course depends on the relation of the complex sound event to the other sounds or to the context of the design. "In order to respect the discursive complexity that is characteristic of all sound events, we can no longer continue to depend on fundamentally conceptual terminology that remains insensitive to sound's phenomenality" (Altman, 1992). Therefore, the sound complexity is hard to define and redefine. The term complexity in the sound design, which I am trying to define, may be insufficient, thus a better term for it remains to be discovered.

3.1.2 Sound manipulation

Sound manipulation and *sound shaping* are vital parts of the generative sound design. When aiming for a constantly changing sound design, the sounds need shaping and manipulation in a way that they will fit with the other sounds and the entire sound environment. Because of the many different sound outcomes, this has to happen with all of the variations of sounds and their textures within the design.

A "*Sound event (gesture)* is a singular/solo sound" (Schafer, 1994, p.159). It can also be referred to as a sound effect and thereafter as a sound Foley. An example sound could be a footstep: it is a singular sound and a sound effect, which can be easily created as Foley (see chapter 3.2.4 about Foley sound).

Sound texture consists of "events with countless sound gestures" (Schafer, 1994, p.159). The sound event can be water, but the texture (pattern) of it is sparkling, flowing, running, dribbling, splashing, and so on. "The sound of rain, or crowds, or even copy machines all have a distinct temporal pattern which is best described as a sound texture… It can have local structure and randomness, but the characteristics of the fine structure must remain constant on the large scale." (Saint-Arnaud, 1995, p.293-294.)

Sound event/texture variation is one of the core elements of generative sound design. It is important to have several variations of the desired sounds for the project. One sound should have many variations of each sound texture: water dribbling 1, water dribbling 2…, and also many variations of each sound event: footstep wood 1, footstep wood 2…, footstep gravel 1, footstep gravel 2…

Because repetitiveness is the thing to avoid, the manipulation of the sounds should fit the texture but alter. As an example of altering the sound with the same sound texture, I will present my interactive sound installation “Sound Surface”, where touching a canvas sounds like touching the surface of water. The sound texture was dribbling water, and every time when the canvas was touched, it sounded different. Dependant on the length of the touch, also the variation of the sound texture changed: I included short, medium, and long sample files with several variations into the design.

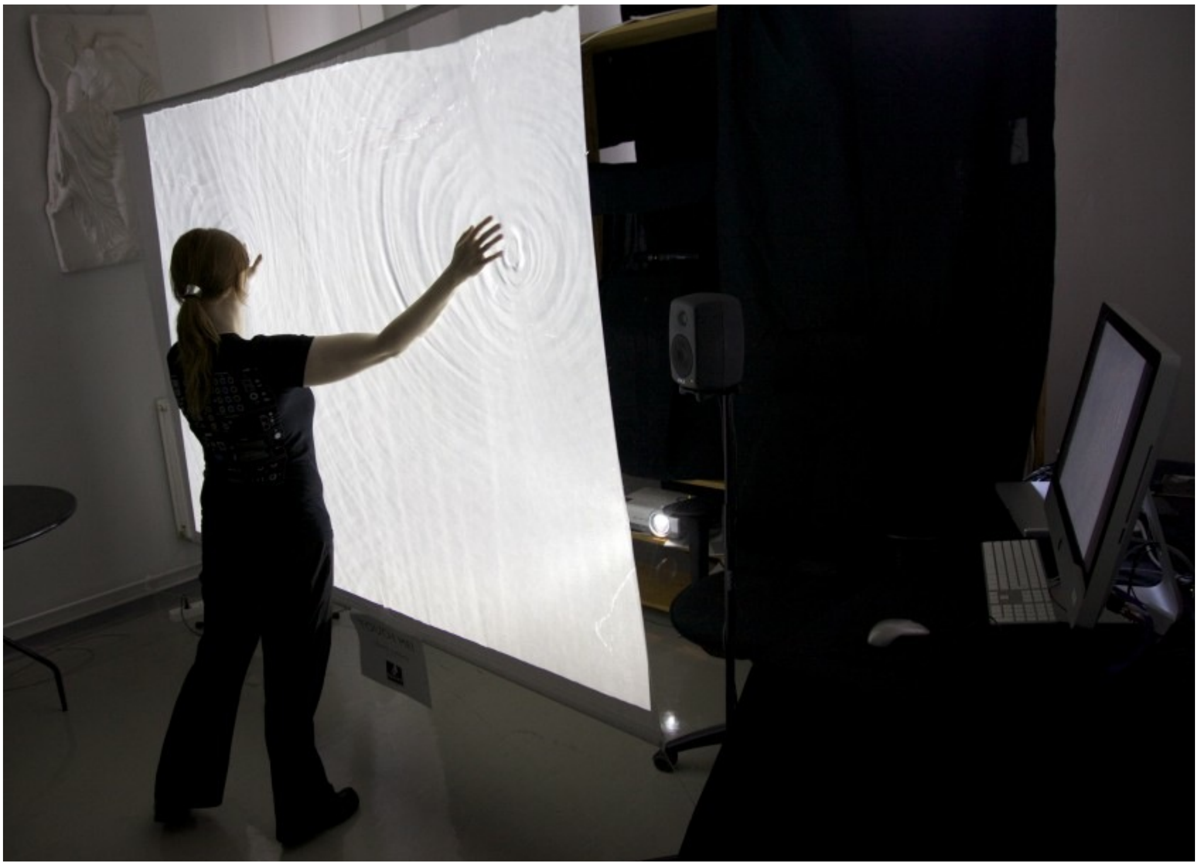

Figure 3.1 Sound Surface by Kirsi Ihalainen (Tourunen, 2013).

Different variations recorded of the same sound increases the amount of variations and textures in the design. Furthermore, from the samples, new variations can also be made digitally and live within the audio engines. The design may have 5 different sound sample variations of the same texture, but the outcome may have 25 different variations of those textures. This sound shaping can be made with the manipulation of the sound parameters, for instance by altering the pitch, volume, rhythm, speed, shape, and length either with the desired rules or with a random outcome. This manipulation can be done with programming in the sound programming software and game audio engines. The shaping may also include building “relationships with the harmonics” and also “highlight effects”, for instance by using reverb manipulation and shifts from sounds to another and triggers to create more variation in the sound (Sonnenschein, 2001, p.60). There are several of these effects, for instance in FMOD Studio, that can be modulated in multiple ways either to a single texture of the sound or to the entire sound event.

Figure 3.2 Random modulations of the sound effects in FMOD Studio.

3.1.3 Sound quantities and grouping

In the generative sound design, the quantity of sounds is higher than in a linear sound design, although the actual simultaneously heard sound quantities might not be more than in a linear sound design. The listener cannot perceive too many sounds at the same time, and in the sound industry this is pointed out with the following example: “If there are several people talking simultaneously, the listener is able to follow only two or three talkers, but able to focus only one at the time” (Aro, 2006, p.23). This also applies to music, where the listener is able to follow only three intonations at the same time, but will be able to focus on only one melody.

Within the sound design industry, this has lead to the design idea of “less is more”, in which the sound design concentrates on the few most essential sounds that are enough to create the illusion or the desired impact in the listener (Sonnenschein, 2001). I would argue that especially in generative sound design this does not hold completely true. The actual quantity of the sounds is not important, because the listener groups the sounds into bigger congeries while listening, and therefore the emotion and immersion plays a bigger role. For example, in most of the latest fantasy movies, it is common to use hundreds of layers of sound to create, for example, a big war scene. Even if it is not possible to hear or distinguish each individual sound, the sound masses are still being perceived with a great impact. It is a matter of organising, mixing, masking, blending, and diffusing all of the sounds together in a balance of several different groups of sounds. Then the outcome of something that is really complex, and has huge quantities of sounds, actually seems and sounds simple.

The phenomenon can be further analysed through the Gestalt psychology. The gestalt effect is the ability to differentiate a visual pattern from its background, and partly, this gestalt effect applies to hearing. With this method, it is possible to separate sounds from each other, the sounds in the front (the ones with a pattern) from the ones in the background. The length and the repetition of the sounds are dependant on which sounds are perceived as the front sounds and which are perceived as the sound background. (Aro, 2006.)

Eero Aro describes the front (pattern sounds) and background sounds according to the gestalt effect in the following way. These could also be referred to as the two levels of the sound depth field.

The sounds heard as a pattern (in front)	The sounds heard as the background
Sudden, loud, surprising and irregular sounds	Dark, blurry, flat, steady and continuous sounds
Human voice and calling	Repetitive and stationary sounds
Short sounds (pizzicato, staccato)	Low sounds, hum and noise

Figure 3.3 Pattern sounds and background sounds based on Aro (Aro, 2006, p.23).

Also the grouping of the sounds can be formulated according to this front-background way that the human ear detects the sounds. These could basically demonstrate the movement of the sounds in our perception. They could be referred to as the perceptual qualities or textures of the sounds. To demonstrate these grouping laws for sound, I have gathered them in the following figure.

Law of Proximity	The sounds near become the front sounds and sounds far become the sounds in the background.
Law of Similarity	The sounds with one or several features, such as the same pitch or texture, create their own groups.
Law of Closure	Series of short sounds (opening and closing), for instance an alarm or pulse, and words in speech, are interpreted as a single continuous sound.
Law of Continuity	One continuous sound can be easily followed, even if two similar sounds play simultaneously that continue as a pattern; one that gradually lowers or another that gradually heightens its pitch.
Law of Symmetry	In symmetry, two different sound sources make a sound that combines into one sound pattern.
Law of Common Fate	Sounds that move with the same speed and direction are combined as one sound pattern.

Figure 3.4 The most important grouping laws for sound based on Aro (Aro, 2006, p.24).

In generative sound design, the quantities of sounds are crucial, especially if the objective is to create a simulation of a real heard sound event. It would be unnatural for an action to have only one existing sound. Therefore, “less is not more”, when it comes to the quantities of the sounds and sound variations. This compounds to an endeavour for the infinite and ever changing variations and textures of the sounds. However, the generative sound design, depending on the context, is programmed with the intent of at least doubling the amount of sounds needed when compared to a linear sound design. Therefore, I would say that the more sounds, the more complex the design becomes: each sound needs to have its behaviour designed. There are also other aspects in the design which may create the complexity. This means that not only a huge amount of sound files in itself will automatically make the design complex, but also the usage of the sounds in the design and the behaviour of the sounds define the amount of complexity.

3.1.4 Sound repetition and behaviour

A *sound loop* is a continuous sound that seamlessly repeats itself indefinitely. The beginning of the sound must match the ending of the sound in order to create a seamless continuation. If the sound loop is too short, or has a recognisable detail or period while the looping repeats, the repetition feature can be easily detected and heard. Therefore the sound has no continuum. For a sound designer, creating a loop should be one of the basic sound design elements to master, although a smooth, continuous, and constantly interesting sounding loop is remarkably hard to implement.

Usually a sound loop functions as a background sound in a sound environment, although a sound loop can be designed to be in sync with an image. The loop can also be interactive; it changes through interaction to another loop. This forms an interactive loop chain with multiple sound loop options. It is possible in a game setup to move back and forth between the loops, to trigger them with movement.

While several loops are playing at the same time, and if all of them vary in length, multiple sound environments will result. Because the outcome is changing and different all the time, the playing of the loops turns the combined outcome towards being generative. In addition, loops can be altered by modifying the sound loop pitch, loudness, and other values in real-time in order to create more complex loop playing and more variety in the outcome.

A good way of avoiding repetition in the sounds is to have several variations of the same sound texture. Also *randomisation* and *chaos* will create the feel of sounds changing and not repeating. Randomisation is a situation that can be programmed to make the computer select randomly from several sound samples the one that it plays. Randomisation can also be applied to the values that alter the effects of the sound. Through interactivity, live parameters can be used to alter and modify the sound events in real-time, which creates the illusion that the sound is always different, because it is dependant on the user. Chaos equals somewhat to randomisation, although chaos can mean that several sounds will play randomly without a more precise ordering or rules. One example of organised chaos is the scattering of sounds, where several sounds will be played after defining the interval, time between the sounds, polyphony, the playing amount of sounds in total, and the distance of how far and close the sounds randomly come from. This feature is also included in the FMOD Studio.

The sound behaviour should be designed in a way that the repetition of the sounds and variations of sounds which remind each other are minimised. When several similar sounds in various configurations are brought together, variation is born, although some longer ambiences may bring variation through time. Complexity can also be how the sounds behave together or how they react to each other. Complexity can be attached to interactivity: the player plays the game; the sound behaves and reacts immediately according to continuous interaction.

3.1.5 Sound masking

Mixing is one of the most important and hardest things when trying to make the entire sound design good in a generative sound piece. One of the problems of this is masking, i.e. “a diminished perception of sound” (Sonnenschein, 2001, p.75). It is a feature that might bring the quality of the design down. While making a mix, it is important to notice whether the louder sounds mask the quieter sounds. “More specifically, the frequency ranges of one instrument mask those of another” (Izhaki, 2012, p.8). This applies to the final generative sound design and is harder to put into balance, when the sounds are generated in a way that it cannot be precisely predicted when they will be heard. This is why mixing for non-linear generative sounds is much harder and needs precise organising in which sounds are more important than others by giving them an importance order. This can be done inside the game or audio engine, and it helps the game engine to work more fluently and save the

CPU memory while playing the game. By freeing the sound event actions, the sound audio engine works more efficiently.

Especially in a game environment, it is recommendable to divide the frequency range spaces according to the sounds within certain areas. This means that if there are mid-range sounds at some point, but they cannot be heard because of the ambience in the background, then for the time being it is necessary to bring the mid-frequencies of the ambience down. Basically, this can be done by applying “live equaliser” changes to the sounds with programming in a generative system, or with an equaliser automation with parameters in the game sound engine. It is good to remember, as Feltcher-Munson states, that with loudness curves, we are more sensitive to mid-frequencies (Izhaki, 2012). This should be taken into account when mixing the final outcome, because people’s ears get tired easily when listening to sounds with mid-range frequencies continuously for longer periods of time. With the combinations of several sounds and their frequencies, this might occur, and these mid-frequencies become a serious issue. Therefore, sometimes some sounds need a complete cut off from the mid-frequencies in order to avoid these “mid peaks”.

In generative sound design, where the sound will vary and change all the time, the combinations of frequencies are greater. Therefore it is important to edit and clean the sounds from unwanted frequencies. The cleaner the sound, the more controllable it is while combining it with other sounds. Also, when creating the sound space with multiple sounds (see chapter 3.2.6 for sound space), either virtually or on a location, it is good to remember that the sound “masking has a greater effect when two same sounds come from the same direction” or are in the same phase (Sonnenschein, 2001, p.76). To avoid this, a separation between the sounds or a phase reversal is required. Overall, the frequency ranges need to be taken under control, as they also have the power to do separation between the different sounds, and therefore have better capabilities to grab the attention of the listener.

Because I believe that masking has a huge effect on the user and the listening experience, I have chosen sound masking as one of the elements to research in my 3D environment study case comparison test. See more about the 3D environment study case in chapter 4.

3.1.6 Discussion about complexity

Many of the interviewed specialists mentioned in chapter 2.6 immediately associated complexity as a term with the behavioural, technical, and variational aspects of sound, as well as the quantities and layers of sound. “Sound complexity is more like a parametric and a technical term. It feels like it refers to the complexity of the sonic parameters within the given sound, how much texture, spectrum morphology, gestural information, spatial information, spectral and timbral information, how much envelope the particular sound has. Feels like quantification of the amount of sonic information contained within a given sound packet. I would say sound complexity is more of sonic properties and less about referential properties. A complex sound would be something with a significant density of sonic information, which potentially means quite a number of layers of sound presented simultaneously, sounds that are maybe very active that include a lot of spectral, gestural, and textural information with a complex activity, density of activity. Complex sound design that engages the listener or user on multiple fronts, using multiple strategies at the same time.” (Andean, 2015.) Therefore the connection of sound to the other aspects of the design was considered as crucial. The designing of these connections forms a complex design, the design inside the design. “Sound is very complex in itself already and a complex sound design uses this inherent complexity of sounds in the way it is creating meanings and is enjoyable to listen to, and it works with our imagination and mind to create different associations between the sounds or inside a soundscape or between the sound and some other media" (Decoster-Taivalkoski, 2014).

The interviewed linked the quantities of sounds to the complexity by saying: the more sounds, the more complex. From this, some issues might occur, as perception has a limited attention span. "Maybe the most obvious way of understanding complexity is the number of objects presented in a scene. There are some basic rules like how many objects we can perceive in the same time or what is the difference between one guy talking, two guys talking, three guys talking and a big group of people talking. The group of people is less complex than say 5 dialogs at the same time. This is a challenge for the sound designer in the complexity level understood as the number of objects at the right level." (Görne, 2014.) Too many overpowering sounds simultaneously make the perception process too complex and therefore overwhelming for the listener. To avoid too overpowering attention grabbers some said they rely on masking, whereupon they are able to strive more towards invisibility and effect with the sounds to the perceiving on a subconscious level.

Layers were most often mentioned by the interviewed. Sound layering was seen as a complex, as a process, and as an outcome. "It is all about the textures and layers of the sound. How the texture works and how it works in context." (Turner, 2014.) The layering and the amount of textures were also associated with realness, because the layering affects how the sound behaves. Furthermore, complex sound behaviour was associated with parameters that could be used to create complex sounds. With the parameters, the sound behaviour becomes complex. The sounds behave according to interactions, which through the parameters becomes the input of the sound system. "Maybe a racing car sound could be used as an example of a complex sound. It consists of an engine sound which has to respond to all the parameters (RPM, load, transmission load, damage, etc), and combine with wheel, suspension, chassis, and wind sounds. All these play together and could be seen as a single complex whole." (Hajba, 2015.) Therefore, the interactivity connected to the sound was according to many a very complex process.

In generative sound design, the source of the sound may form some limits to complexity depending on whether the sound is a pre-recorded sample sound or synthetic and procedural. "The vintage waveform based, synthesised sounds could be seen as simple, where samples could be seen as complex. But a sample alone cannot be altered much beyond pitch and volume, where a synth chip may have a rather complex code behind it to play the sounds." (Hajba, 2015.) This constraint in sound flexibility and the complex ways of using the sound with interaction might actually lead the way for procedural sound design.

However, the professionals emphasised that the design should not be too complex while something simple might work better. "The demand for complexity might be destructive. We easily lose the value and potential of simple things, simple materials, simple messages, one layer, one thing that communicates with the listener is often fast and more powerful." (Andean, 2015.) Nevertheless, sometimes something complex can become something simple and vice versa, or naturally something simple will remain simple and something complex as complex. However, by making things too difficult and complex, the result might be very messy. "It's not always a good idea to make a sound overly complex just for the sake of complexity. It may end up confusing. Speaking of candy colours and complexity, Peggle 2 featured a rather complex music system that matched the peg hits with notes that were always in key with the background music. This is complexity put to good use." (Hajba, 2015.) Therefore, I would say that the sense of how to use complexity, or to which extent complex methods should be used in order to get great a sound outcome, is something that the sound designer has to figure out by rationalising his/her creative thinking in the design.

3.2 Sound design realness

Realness is one of the key elements in sound design and especially in the process of creating sounds. Without a sound source, it is hard to create a specific sound or even a similar sound. For instance, it is quite hard to fake the sound of a human or the sound of a certain object. However, when creating tailored sounds (see chapter 3.2.4 for tailored sound), it is sometimes easier to fake some sounds, such as the sound of snow with amylum. Nevertheless, the sounds are all recorded sounds, and therefore their texture sounds “organic”. When it comes to the realness with sounds, I would call it a term that includes the battle between “organic” and “computerised” sound. The computerised sounds are created from digital data only, they are synthetic. A further study lies in the differences of the perceptions of these two. Nevertheless, I believe plausibility and immersion can be achieved with both.

Realness is mainly distinguishable, when the sounds are within context; when the listener judges whether the sound is believable, plausible, together with the other aspects of the entirety. Also the narrative content and the genre of the narrative create the rules for realness. Because of these genre rules in sound design, the listeners will accept sounds that are not real in real life, if they fit the content. According to Nilsson (2012), who studied the perception of realness in horror films, “Film sound without an obvious origin within the narrative doesn't necessarily break the illusion of realness” (Nilsson, 2012, p.6).

3.2.1 Terminology

The term realness can be referred to as a thing or entity that has an actual existence. Realness also means a genuine origin or a genuine product. Within sound design, I would link the term realness to a sound source and our ability to recognise that sound source, or to a situation where the listener experiences the sounds as real within their context; the sounds are believable. To be more specific: “We usually use the term “realness” to mean our sense-ability: what our senses sense. This “sense of presence” is independent of whether the material is derived from the real world or from a fantasy based one (perhaps “thereness” is a more appropriate word than “realness”).” (Naimark, 1990, p.1.) Therefore, realness is more of an understanding of what the presence is and has little to do with the actual reality. Realness is rather the effect caused by plausibility. The effect is so real that the listener believes the sounds are true.

According to media researcher Michael Naimark, the film industry understands realness but not interactivity, and the computer world and game industry has it the vice versa. These two worlds are still in the process of combining. The aim is to create an experience as real and immersive as possible, even though instead of a real picture, the game industry utilises animated techniques. Even if the sound world is ‘real’ or plausible, it does not make the experience equivalent to a real life event. Nevertheless, according to many, the aim in the game industry is not to create a simulation of reality.

3.2.2 Plausibility and immersion in sound design

The main goal in creating plausibility in a sound design is to create an illusion that the audio matches the other aspects of the work. In games and art installations, the sound may not be meant to be as realistic as possible. (Reiter, 2011.) "As long as there is no obvious contradiction between the visual and the acoustic representation of a virtual scene, the human senses merge auditory and visual impressions" (Reiter, 2011, p.159). I agree that due to the constraints of the computational power, the human perceptual differences of reality, and the lack of time and investment, it is hardly possible to create a "perfect reproduction" of a real life representation or simulation. Therefore, it is much more important to concentrate on creating the most crucial parts of the representation, in both visual and sonic worlds, which together will make the perceived illusion plausible in the user's mind. A sound designer is required to find these parts that sonically create plausibility.

Plausibility with only sound and no visuals is easier, because with the audio, the blending, layering, and matching of different and several sounds is possible simultaneously, unlike with visuals. When visuals are included, the sound has to match the seen visual object. "We are very sensitive to sound, more sensitive than to visuals. So, it is hard to trick the ear that what we are listening to, is authentic or at least believable." (Weir, 2014.) Even if only one function of the sound is not serving its purpose, the sound becomes ineffective and unconvincing, because "The brain is highly attuned to what is *"right"* " (Weir, 2014).

One crucial effect, which may bring the quality down when trying to make the sound design plausible, is the selective attention. While it is quite impossible with limited computational power to create a perfect representation of the virtual environment, "it is reasonable to focus only on the most important stimuli and leave out those that would go unnoticed in a real world situation" (Reiter, 2011, p.159). Findings in several studios indicate that the "perceptual process is actually controlled by the attention" (Reiter, 2011, p.164). Therefore, with an accurate attention guiding of the listener or the user, the sound design is perceived more according to the way the sound designer has intended, or the experience is perceived as intended.

The concept of sound being believable within context is also often related to immersion, especially with the game audio. Immersion is "characterized by diminishing critical distance to what is shown and increasing emotional involvement in what is happening" (Grau, 2003, p.13 in Collins, 2008, p.133). Immersion can also be thought of as getting the listener "to be part of the imaginary world" or "identifying and having emotional bonding to the character" as "seeing elements of the character in him- or herself, and elements of him- and herself in the character" (Collins, 2008, p.133) or "deep mental involvement" (Liljedahl, 2011, p.43). Immersion is still under debate; how it can or cannot be controlled.

Immersion is highly dependant on the quality of the sound design and audio, which is why "The use of sound does not automatically create immersion" (Liljedahl, 2011, p.26). The sounds make the imaginary world come alive, when the sound fits the purpose and creates "naturalness" in the experience. The actual real world sounds of the sound objects might not create immersion, which is why a "reproduction" of the sound is not enough (Collins, 2008). The sound also needs to have certain characteristics, when combined with an image or an action.

This leads to why I think that the sound can have multiple personalities; aesthetics, that can have several different effects on the listener. Therefore it is crucial to find the best personality of the specific sound to fit the context, and to create the wanted emotional immersion that creates "realness" to the listener. An example of finding different personalities of the sound could be when an animated coffee pan whistles. What kind of whistle is needed? Is the whistle humorous, alarming, settled, sad, happy, angry; the choices are numerous. This means that each sound texture can have several varieties that can have different personalities as a result, when combined with an image.

In games the immersion is studied through the flow concept. It evaluates the gaming experience and the amount of enjoyment. "Flow: The mental state of operation in which a person is fully immersed in what he or she is doing by a feeling of energized focus, full involvement, and success in the process of the activity" (Liljedahl, 2011, p.43). The better the flow in the game play, the more the enjoyment; and this results in better concentration on the experience and immersion.

When creating a sound space with sounds, the immersion has an important role. If the sounds do not create immersion, the sound space does not surround the listener, and the listener will be detached from the imaginary world. Therefore immersion can be lost easily; it only needs one sound that the listener cannot attach to the imaginary world or a programming mistake in the game world, which makes the sound behave faultily. This immersion is something I tested in my case study with the 3D environment. There were plenty of different factors that influenced the immersive experience of the listener, either by disconnecting or by compelling.

3.2.3 Sound narrative

The sound has several tasks in storytelling and in focusing the attention of the listener. The sound itself should always have a purpose or focus and a supporting story. I personally believe that when the sounds lack in story, the soundscape is just a series of sounds one after another. The sounds need to have a consistent design line in order to successfully deliver the sound narrative to the listener. Sound therefore requires time and consistency to create connections between the experience and the listener, and it is mainly possible through associations to evoke emotion in the listener with the sound. The sound is always learnt and only through this evolves into a perceptual awareness. With the narrative in sound, we are able to trigger both primary and secondary emotions. The primary reflects the emotions of the character: a sound heard by the character that causes an instant reaction in him/her; and the secondary is the audience's emotions: a sound not heard by the character but only by the audience that causes a reaction in them. (Sonnenschein, 2001.) Through this categorising of the emotional reactions, it is possible to engage the listener in different narrative ways.

Also the sound space (see more in chapter 3.2.6) is felt and heard on a narrative level. Even though the sounds should be as clean as possible, sometimes recording the sound in an acoustically rich environment brings a narrative twist to the sound, and the feel of the space in the sound may create a certain feeling in the listener. (Sonnenschein, 2001.) Basically the story is created with time and place (Schafer, 1994). While the sound has a history, it can be easily linked to the era of the story. Even if these sounds were in the background and heard unconsciously, they create the emotional attachment to the location of the story. With sound, the emotional locational shifts are possible; for instance in films, quite often the location might be inside the character's head and mind. This can easily be done with the sound design only.

When the sound is ambiguous in the design, it might create more layers to the narrative. According to Liljedahl, “By planting a well-designed sound at the right moment, you can trigger a person’s imaginative and emotive mechanism by forcing her to consciously or subconsciously interpret or disambiguate the sound. Leaving the user space open to her own interpretation, inviting her and giving her the freedom to use her own imagination can potentially gel the user to be emotionally and viscerally involved in the game.” (Liljedahl, 2011, p.30.) There can also be layers that create emotional associations to the characters. For instance in Star Wars, the fighting laser sword sounds are tuned to different pitches, minor for Darth Vader and C major for Obi-Wan Kenobi, and during the fight they form a dissonance (Sonnenschein, 2001). Some characters may also have a personal sound which plays, when the character is on screen; this makes the viewer attach the feel of the sound to the personality of the character.

Among the space and the character sounds, some sounds can be also interpreted as universal, historic, and culture based (Sonnenschein, 2001). These sounds may have a strong historical background or brand behind them, which people immediately realise when the sound is heard. These sounds can be used to underline or build the narrative, if they are relevant to the story.

3.2.4 Organic and tailored sound design

Tailored, individualised and customised sound effects will elevate the quality of the sound design enormously. The sound designer needs to figure out what something sounds like and make it into reality for the listener. Also Foley sounds, which are created by sound Foley artists in the sound recording studio, are tailored sounds and mainly fit the purpose that they are being recorded for. It is really hard to fake an action or an object with a sound that does not fit perfectly or is out of sync with the image. (Ament, 2009.)

It is very likely that a recorded sound will make an organic realness to the sound. This organic feature comes from the fact that the recorded sounds represent the real life objects that have been recorded. If the sound was made digitally only, it would be like a 3D modelling of an object; it is only a model not the real object. Capturing the object on video would be similar to recording the sound of the object.

The film industry sound design has shaped our perception of sounds quite tremendously, for example in how we hear the wind in the trees or a punch of a fist in a fight. A Foley sound artist may create the sound of the wind with the mouth and hit a bag as the punch. Thus, the Foley artist creates sound from sources that are not the same as in the image, but because the audience believes it, the sound becomes plausible (see chapter 3.2.2). This is possible, because the Foley artist follows the image and is able to sense what kind of a sound and the texture of it fits with the action. Therefore the artist is able to tailor the sound for the purpose. (Ament, 2009).

I often hear comments about how already gathered and pre-recorded library sounds are easier and faster to use. Sometimes this is true, when the sound does not need that much altering and modification. Then again, sometimes the outcome may sound detached and the feel of the sound has been glued to the image. This also means that the sound is recorded by someone else; therefore it might bring negative associations to the effort or professionalism of the sound designer. However, it is understandable that the sound designer cannot record sounds of something unreachable, for instance wild animals or ambience sounds from another continent.

The main goal with the tailoring of the sounds is that they fit the purpose, rouse the wanted feelings and enhance the experience of the listener. It is obvious that if the sound does not fit the image or context, it gives the impression to the listener that something is wrong, distracts, or alienates. (Ament, 2009.) There is a risk this might even ruin the entire experience. In the library sounds, several variations of a single sound might not exist, which, especially in generative sound design, is one of the most crucial elements. The sound constantly changes and the repetition of the same sound detaches the listener from the experience. Therefore it is crucial to record as many variations of the same sound event as possible. Each Foley sound should have multiple variations with multiple lengths. Sometimes even several different words of dialogue can fit the image of one mouth movement and can be plausible to the listener. This is especially true with coughs, sneezes, screams, and many others. Therefore the sound dictates the movement on the screen and creates a visual illusion.

3.2.5 Procedural audio vs. recorded sound

While procedural audio has the purpose of being able to alternate its sound texture in real-time almost constantly and has a low memory capacity, as it is based on only data, the recorded audio is still overpowering with its effect of an 'organic' feel, even though the demands are bigger for the storing memory.

For now, no significant proof on whether people notice the difference between a procedural and a recorded sound has appeared. Overall, it is assumed that a recorded sound is still quite distinguished from a procedural sound. However, in a small research and comparison test made by The Aalborg University Copenhagen in 2013, where a sword fighting game scene was played twice, once with pre-recorded and once with procedural sword sound effects, some interesting conclusions were drawn. As a result of the test only 5 people of 17 noticed a difference in the sound, which equals to 29.41% of the test people. The rest said the sound was the same in both scenes. (Böttcher et al., 2013.) I personally believe this would require more user testing with a larger volume.

According to Martin Roth (2014), procedural audio is "lacking in design principles, tools, and technical performance" and also "suffers from a lack of resources", which is why the teaching of how to make procedural audio is inadequate. Therefore the usage of procedural audio is lacking while it is possible to create it only in the audio programming languages. "Unless the designer can run the sounds on the target platform, the tools are not helpful except as a part of the creative process. A dearth of design resources, incomplete tools, and poor performance. That's why procedural audio hasn't taken off." (Nair, 2014.) However, procedural audio has a lot of advantages, and it is still in the process of being utilised to its best. The advantages and disadvantages can be seen in figure 3.5.

Summary of pros and cons for Procedural Audio

For	**Against**
Rapid growth of product size	Shortage of audio programmers
Demand for more interactivity	Established production methods
Increased processing power	Lack of development tool-chains
Deferred aesthetic settings	Outsourced content producers
Huge body of research potential	US market closed by patent trolls
Automatic physical parametrisation	Physics engines designed for graphics
Simpler asset management	No effective open DSP engines

Figure 3.5 Summary of developmental factors (Farnell, 2007, p.26).

While procedural audio is making its way to games, it has been seen as an opportunity to create fast and efficient audio with interactivity. Also game sound designer Peter Hajba has pointed out some advantaging factors about the usage of procedural audio with games:

Space efficiency	Massively smaller, orders of magnitude smaller in fact.
No libraries	No searching for that lost glass smash noise, so faster development once you have a few algorithms in your toolbox.
Uniqueness	Your games or media application sounds will be unlike anybody else's.
Real-time parameterisation	Sounds are defined as they are created on the client.
Coherent object modelling	Factoring code from physics and 3D object properties with sound for a unified approach.
Object re-usability	Write code that can be scaled or twisted easily into new uses.
Dynamic runtime LOD	A different approach to mixing where the actual nature of sounds change not just their level as they move into the background.
Architecture/bit rate independent	Future proof, your algorithms will run in ever higher quality as the hardware improves.
Also	No editing, looping, normalising and tagging of thousands of files. No royalties or problems clearing some obscure recording, everything generated from first principles.

Figure 3.6 Summary of procedural audio for game developers (Hajba, 2015).

Some new solutions for utilising more procedural audio have also been published. An example of this is the solution for integrating procedural PureData sound patches to a game audio engine with a new procedural audio workflow, *Heavy,* which is created by Enzien Audio. Heavy is an audio data flow language with which PureData can be turned into other programming languages, such as C or Javascript, and it is therefore attachable to the audio engines, such as Wwise and FMOD. Also other ideas, for instance software to create a "virtual Foley artist" and some other integration solutions have been developed as results of academic research. However, with academic research, the problem might lie in the fact that the solutions will not be developed further commercially. (Procedural Audio Now, 2014.)

There have been some innovations to teach the computer the textures of the sound, such as the *audio texture algorithm* that would generate from tiny pieces of a short sample file into a longer version, a "synthesised audio stream". This would save memory capacities, as the audio would only be derived from data. (Lu et al., 2002.) The audio texture is a possibility, although a very complex one. However, a software based on this idea has been created by Karlheinz Essl. The software is a generative sound file shredder based on granular synthesis and called REplay PLAYer 4.0. (Essl, 2013.)

However, I believe that the most important problem lies in the issue of the procedural audio being able to mimic the recorded sound in as good and versatile ways as possible. Procedural audio has challenges in being able to reproduce in detail the feel and the effect similar to the original sound. The implementation would require time to explore the original sound in order to be able to create a similar sound with data only. I heard one sound designer saying that during the time spent in creating one sound as procedural, he would have grabbed a microphone and recorded the same sound with several variations and also already placed it into his mix. In addition, the memory capacities of technology devices are growing all the time, whereupon also recorded audio gains more memory space all the time, as the file packaging business is a very hot topic at the moment. Therefore, recorded sounds will not be replaced easily. Also, at the moment, procedural audio is not developed enough technically to be as versatile as an original sound from a sound source, and the process to create and implement procedural sound is not as fast enough.

Furthermore, I believe the procedural plug-ins should include several different sounds and not only one or two sounds per plug-in, because running several plug-ins may take more processing power than several sounds within one plug-in. Nevertheless, the procedural plug-in should be taught the versatile behaviours of the original sounds. This requires more programming for the creator of the procedural sound plug-in. Therefore, the generative sound design will not be able to only rely on procedural sounds, at least not at the time being, especially when combined with an image. However, procedural audio has many advantages, and it will definitely lead the way of generative sound design. The question of whether the procedural sounds create as efficient and powerful emotional impacts as the original sounds remains to be answered.

3.2.6 Sound space and diffusion

The sound space can be thought of as a space created with sounds; it can be referred to as the imaginary world, sound environment, space with ambient sounds and many others. There are several different sound spaces: a sound space in a virtual media platform, a sound space in films as the filmed location, or in a real space/location created with a sound installation or other multimedia. The creation of a sound space for an actual location is much harder, because you are not in control of the sounds all the time, and the design is linked to physical acoustic variables affecting all the sounds at all times. It is problematic for the sound designers to “create spaces that accept the whole universality of the ambient space, and be aware of the outside world that will invariably intrude on this design. Therefore sound design must create a sense of displacement or removal from the real, while accepting that the real will equally intrude on the virtual experience.” (O’Keeffe, 2010.) The cues which “define our perception of space and its various aspects” are “size, distance, perspective, directionality, subjective/emotional space, and movement” (Sonnenschein, 2001, p.83).

When talking about the sound space on a real location, a vital part of the quality of the sound design is the environment, the actual space. To understand the sound behaviour with the exogenous factors, it is important to lift the design to a level where the sound itself does not suffer surprising setbacks. Even though sound is very abstract, the output of it is still always a physical feature. Whatever the space is where the sound will be heard, it creates a characteristic personality to the entire design. “Social space is a sonic space. Space is the register in which sound can happen and sound can have a meaning. But space is not a static thing. It is in constant formation, dissolution and reformation.” (Sterne, 2011, p.91.) Therefore the sound design is not the only sound existing in a space. There are other sounds and sound objects, either constantly or temporarily, in the same space. These sounds also vary, and depending on the space, they are very unpredictable. Because sound is territorial and is also closely linked to behaviour, culture and pretty much everything within its territory, this needs to be taken into consideration when designing the sound space onto a location.

Sound space design, in other words, designing a site-specific sound installation, can also be referred to as a *diffusion,* which "is the projection and spreading of sound in an acoustic space for a group of listeners… Another definition would be the "sonorizing" of the acoustic space and the enhancing of sound-shapes and structures in order to create a rewarding listening experience." (Gibbs, 2007, p.135.) The creation of a sound space design includes an acoustic experience, "it refers to both technical means of simulating acoustic and spatial phenomena and to the semiotic processes which generate meaning by creating new forms in the space medium (Luhman 2000: 102-132)" (Chagas, 2006, p.134). Therefore space is a very generative territory. Even while maintaining its characteristics, it is still always changing and vibrantly different all the time. After all, "space is not just a container nor just a context for action. It is generative and always in flux, as are our perceptions of it." (Sterne, 2011, p.92.) When designing generative sound spaces, it is important to know how versatile a certain space is with sounds, and while creating the sound space, all the different variations of sound textures and the sound events within the space should be taken into account. This is especially important when recreating a virtual generative acoustic sound space.

I consider my second study case of Finnish Forest Frequencies as a sound space installation, as I have 8 channels which create a space using sound onto a location. For installations with diffusion, it is very common that they include several channels of outputs/speakers. Examples of these are Edgard Varèse's Poeme Électronique, which is site-specific sonic art diffusion installation with more than 400 loudspeakers (Gibbs, 2007), and The Murder of the Crows by Janet Gardiff Gearge Bures, that I saw in the Museum of Contemporary Art Kiasma, which is a sound play installation with 100 speakers and using space as a tool to create the sound illusions within the space.

3.2.7 Discussion about realness

Realness as a term is not commonly used among the sound designers as such. However, the thought of the meaning behind it is more common, and a term for it is under development. The term has only a slight reference to reality according to the interviewed professionals, because the approach of the design rarely aims to be like the reality. A sound which is real to the listener can be constructed with any tools, only the compatibility of the sound with the content is important. "Sound can generate images in the head of the people. It does not matter how it was created, if it was recorded or not. It depends on the situation where you use it." (Moreno, 2015.) Many said it is only a matter of taste or how the sound designer prefers to work, whether to use recorded or synthesised sounds, or even both. It was clear to the interviewed that what the listener hears and assumes as real sound events become the 'reality' of the experience to the listener. "Perhaps the term here is *realism* rather than realness? Many modern games try to go for realistic sounds, from Foley to guns to vehicles and weather. These are fairly easy to come up with via sample playback. But there may be some more abstract elements in an otherwise realistic-looking game, such as magic or aliens. These will require a more abstract still seemingly realistic design. But as to what is real, maybe it's just a philosophical question? A Mario jump sound can be just as real as the pull-and-release slide sound of a real world weapon based on Battlefield assault rifle. If it serves the game well, it is real to the player." (Hajba, 2015.) Realness could happen at the moment when the sound has been accepted as believable and real within the context. "The realness is whether you accept this specific sound to this specific context" (Nispen, 2014).

However, the source of the sounds seems to matter to many of the interviewed. Many made it clear that the recorded sounds have organic qualities. The organic feel was the reason why they wanted to use recorded sound rather than synthesised or procedural. More importantly, they wanted to be the creators of these sounds by recording the sounds themselves and by processing them as they imagine them. However, sometimes when working in a hurry, the libraries are the makeshift at hand. “Most sound designers combine everything they have at hand, sounds from commercial recordings mixed with their own recordings, and synthetic sounds added as sweeteners. Sometimes synthetic or manipulated sounds are the main ingredient, if the game for example has a SciFi setting. As for realness (realism) the sounds need to be in context. If the game is a brightly colored candy themed fairytale game, the sounds need to be matched to that.” (Hajba, 2015.) Mainly, the interviewed thought that the sound designer should really design; it was important to everyone to personalise their own design, to make it theirs. “Anybody could be a sound designer, but if I have to get back to the roots, and be like what is sound design by definition, it is a creation. You can start with libraries and create a great sound and it is still the work of a sound designer because it can become very unique depending on the sound designer. It is much more about how you use it to create your own sound.” (Deriviere, 2014.)

Sometimes the realness can be based on previously created assumptions of sounds, such as the Foley sounds and how something sounds in the films, even if the same sounds do not sound even closely the same way in real life. This might have developed into a power symbol behind the sounds, and therefore what the sound symbolises is more important. Then it does not matter even if the sound is fabricated and does not correlate to the same sound in reality. “Realness is a corner stone for traditional sound design, how real the sound is, how closely linked it is to the imagined source, and how well recorded and presented that is. If it is supposed to evoke an image of waves it is more real if you’ve gone and recorded waves than if you’ve used a white noise generator to craft waves, that’s one. Other one is how real it is in terms of the directness of the image it evokes, and those are very different questions as we know. The realness in terms of supporting the symbol we have for that object vs. the actual sound actually made by it.” (Andean, 2015.)

Many of the interviewed said they work with both recorded and synthesised sounds in order to combine them and create something magical to the sound, to make it a little supernatural, to create more feel to the sound. Maybe this symbolism and magic of the sounds is something that makes the listeners believe the sounds are real within the context. However, the sound is what it is, and making the sound into something completely else might be difficult, as the quality of the sound diminishes according to the amount of processing: the more processed the less quality. “The sound has a soul, which you cannot process” (Struck, 2014).

Also other things effect how the sounds are being perceived as real. Sometimes the visuals affect sound perception and shape how the sound is being heard. “Often the sounds you generate may not sound real by themselves but against the picture they may completely work” (Nielsen, 2014). It might also be a human need to believe the sounds are real, and according to lecturer Marianne Decoster-Taivalkoski some research on the matter has also been done. “It is a convention between the audience and the work. You believe those sounds are real, it is the desire of fiction, the need of believing that something is true.” (Decoster-Taivalkoski, 2014.)

The sound may also have some behavioural effects on realness, and thus the sound in a generative sound design could be made closer to being real. A repeating static sound is not as alive as an all the time changing sound. “Static sound as a general rule tends to feel unreal regardless of the source, things like recording a waterfall, because it is basically an unchanging paler. Sound timbres and textures that don't change we attend to associate with electronic or mechanical sources which we somehow feel are less real than organic sources." (Andean, 2015.) In a generative sound design with the behaviour of several variations and textures, the realness of the sound was considered by the interviewed to be something that makes the object come alive, more real life like. According to some of them, this is mainly achieved with complexity, which is very close to realness and a sound behaviour in itself.

3.3 Sound design quality

It is more than hard to define the quality properties of a sound or a sound design. Audio qualities are more often related to actual technical qualities. A higher frequency rate and a bigger bit depth are often thought to lead to a higher and better quality of the audio file. This is true to some extent, though, after a certain point, it is not possible to tell the difference between high rates and bit depths (Archimago, 2014). This is because our physical hearing is limited in this way. Actually what this means is that the technical quality becomes unimportant when listening to a sound piece or sound design. When listening to any sound work, the actual technical quality nowadays is almost always pretty standard of a good quality. What it actually means is that the quality is something that is dependent on the sound designer's aims and contributions towards the relevance and story for the sound design.

Sound design quality is a combined setup of many relevant things, such as the features and processes covered in this thesis so far, and together these features define the quality in the ear of the listener. However, it is still unknown how obvious the differences in sound qualities are to the listener, because many other factors affect the perceiving experience; especially the quality's interdependency with the image and the impacts of interaction. With the help of listening tests, some results have been found. However, the sound design quality has been defined in terms of aesthetics and effectiveness, which are difficult to measure. In order to find out the quality of one's own design, another pair of ears always helps.

3.3.1 Terminology

The word quality is often associated with something that is either superior or non-inferior. The word itself also strikes as a way of measuring and evaluating the outcome with a certain critique. Even though it might seem like a negative thing, it can be turned into a positive meaning. With good quality, we are able to enjoy more, make things easier, and it also gives us as a happier impact. Overall, quality is something that improves the experience. I personally think that there is no such thing as bad quality or good quality. The word quality already in itself is a statement of a better something. When talking about sound design, this would be a quality sound design (good sound design) vs. bad sound design.

It is important to separate the quality of a single sound from the quality of the sound design. The quality of a single sound is often defined by the quality of the technical properties, and the quality of the sound design is mainly defined by how effective the design is or whether the sounds support the narrative. Within the sound design, the technical qualities of a single sound do not matter. However, if the overall technical sound quality is really bad, it will distract the listener from the story or alienate him/her from the experience. That is why I chose this aspect as the quality element in my 3D environment study case comparison test (see chapter 4).

3.3.2 Assessing sound design quality

The measurement of the sound design quality is a very difficult process because of so many alternative factors that influence the outcome. To be able to have some measurements, it could be possible to measure the final aim of the sound design. If the sound design was aimed to result in joy in the listeners but instead accomplished sadness, then the design failed to do its purpose. “A quality sound job is an effective sound job for whatever it is trying to do. It is accomplishing something. When I think of quality films, I am thinking effective films in a way. When I want to measure quality, I would want to see how effective something is in accomplishing something.” (Nielsen, 2014.)

Quality is always determined perceptually with personal biased opinions. However, in a sound design, the quality could possibly be specified into some sectors. These sectors could be the technical skills of the sound designer that can be heard as the technical quality of the entirety, the aim or purpose of the design, the idea or meaning behind the design, the flow of the sound design, and the actual outcome or final representation of the sound design.

The quality of the sound design is something that I think of as the aesthetic value of the sound design. This aesthetic value is based on the meaning behind the sounds and the idea of the sound work itself. Only when a meaning or an idea is present in the sound work, it can have an aesthetic value. “The emotional, physical, and aesthetic value of a sound is linked not only to the causal explanation we attribute to it but also to its own qualities of timbre and texture, to its own personal vibration” (Chion, 1994, p.51). The aesthetic value can be criticised by whether it really fulfils the purpose and delivers the message to the listener. “May “beautiful” and “ugly” be however silly, without them there is no aesthetics. If it was left unsaid “it sounds more beautiful” we would be left with a hardly fillable gap in our expression.” (Kinnunen, 2000, p.41.) However, a good art work means something totally different than a beautiful artwork according to Kinnunen, because good art work requires knowledge of the origin of the art piece. Calling something beautiful or ugly is an immediate response. This will be the case with visual arts, although when talking about sound, I think it would still be referred to in terms of “sounding good” or “sounding bad”.

Kinnunen also says that the aesthetic terms, such as beautiful and ugly, can only be said of the entirety of the art piece, and that the “aesthetic experience is an emotion and justified with aesthetic terms” (Kinnunen, 2000, p.251). According to Kinnunen, the evaluation of the art piece with these terms could happen by “the evaluation of skills, effectiveness, significance, interpretation of the piece, and the cultural status evaluation of the art field and the art piece” (Kinnunen, 2000, p.300). It is then possible to say that the skills of the sound designer and the effectiveness of the design affect the aesthetic value of the art piece and therefore affect the quality.

If only a part of the sound design is measured, then this becomes harder. This is because “our auditory system has a very quick settling time, and it gets used to different sonic qualities as long as these remain constant for a while. In essence, all our senses work that way.” (Izhaki, 2012, p.8). This means that the entire sound design can have this aesthetic value rather than a single sound, which is pulled out of context. However, an artwork can consist of a single sound only, although then the sound must have a narrative purpose behind it.

There are several influence factors that affect the quality impression. Ulrich Reiter created a salience model in his research about perceived quality in game audio and listed these quality influence factors (see figure 3.7). The most influential factors are the sensory perception and the cognitive processing, and the quality attributes can be thought of as the actual interaction process with the sound. Nevertheless, all these aspects affect the quality impression. (Reiter, 2011.)

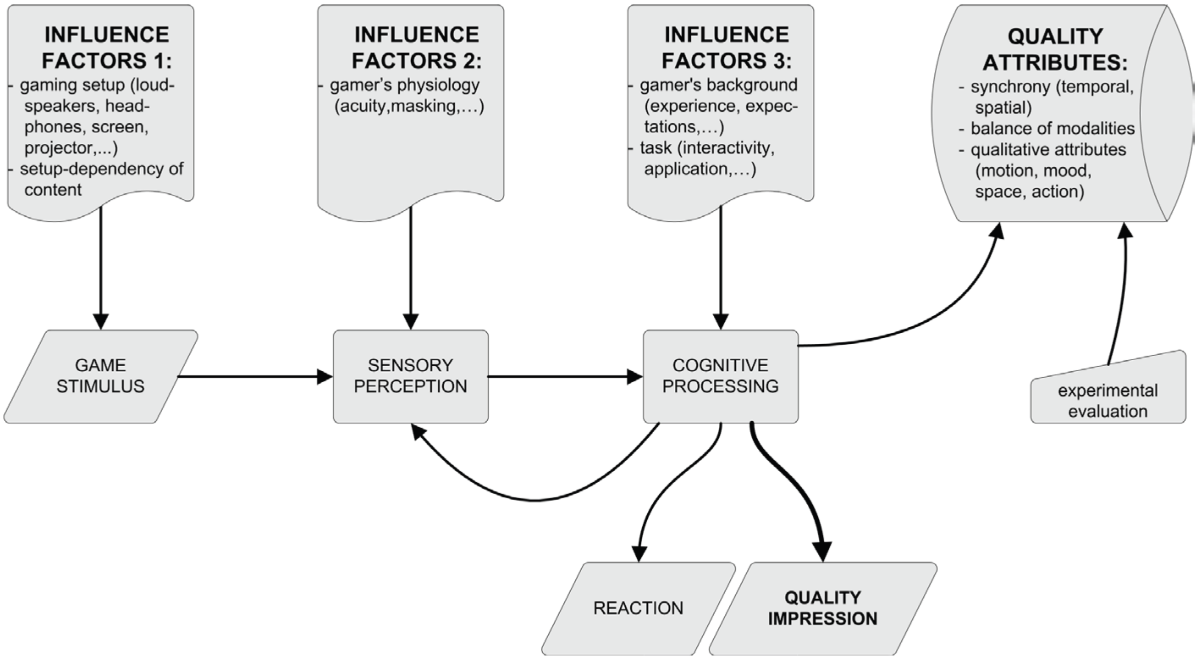

Figure 3.7 A salience model for perceived quality in audio-visual games (Reiter, 2011, p. 166).

When the impression of an experience needs to be described, these verbal evaluations of sound can become problematic, especially with differing interpretations of the meaning. “The way people describe their images depends on their habits of outlining” (Aro, 2006, p. 26). According to this, Aro divides people into three different basic types and to their mixtures: the *visuals,* who learn the best through vision, the *auditive* through hearing, and the *kinaesthetic* through doing. The evaluation also depends on the person’s expertise in life or profession, which will dominate the way that perception is evaluated. For instance an acoustics engineer will describe music in a space differently than a regular listener. (Aro, 2006.)

Through psychological listening tests, it is possible to research whether the sound event creates the desired perceived impact. According to Aro, the following experimental setups are used in the psychological research studies for user subjects. The perceived impact objectives are to discover the detection or difference thresholds of the user subjects. The experimental setup examples are presented in figure 3.8 and the sound listening test examples in figure 3.9.

Experimental setup in the psychological studies:
Describing the sound stimulus perception either with words or by drawing.
A test situation, where the test user adjusts the sound stimulus until it equals the desired value.

A selection method, where one sound is chosen from two or several sounds, for instance due to being different from others.
A method of tracing, where a test user influences the features of the sound, for instance by pressing a button to increase or lower the feature.
A screening method which is a variant of the previous arrangement.
Yes or No answer, where the test subject decides whether the sound stimulus is detectable or not.
Reaction time measurement, where the reaction time demonstrates the difficulty of the decision making; the amount of mental processing.

Figure 3.8 Experimental setup in the psychological studies (Aro, 2006, p.27).

Sound listening tests for test subjects:
AB-test, where the test subject organises the A and B samples according to feature into a preference order.
AB-scale test, which equals the AB-test, however a numeric value needs to be assigned to A and B on a given numeric scale.
ABC-test, where A is a valid comparison factor to which B and C are compared.
ABX-test, where the inquiry is made whether A or B equals to X.

Figure 3.9 Sound listening tests for test subjects (Aro, 2006, p.28).

I decided to create my questionnaire for the users in my 3D environment comparison test based on the setup of an AB-test by including some of the experimental setups as the questions (see chapter 4.3.2 and appendix for the research interview questions).

3.3.3 Auditory vs. visual experience

It is a known fact “that an improved quality in video can also increase the subjectively perceived audio quality, and that the reverse affect also exists (Breeders & De Caluwe, 1999)” (Reiter, 2011, p.154). The power of observation is limited, because listening is always an action that requires effort (Schnell, 2013). If the image draws the attention away from the sound too much, it garbles the listener’s focus and deteriorates the attention towards sound and its quality. It also means that too much excessive and cognisant attention towards sounds may also twist the perception of sound quality. That is why it is hard to say what the perfect or the right way to perceive the sounds correctly is, or how the sound designer meant the sounds to be heard.

It is quite obvious that both our visual and auditory ways to perceive things have similarities and differences. However, we combine all our sensory perceptions into one “multimodal whole” (Liljedahl, 2011, p.23). This way of mixing perceptual input simultaneously is natural to us. There are three examples that Liljedahl presents. The first one is the “McGurk effect (Avanzini, 2008, p.366)” that demonstrates the way the visuals affect what we hear. The second one is where “what we see shifts the sound (O’Callaghan, 2009)”, and the third is called “global array” by Stroffregen and Bardy, where we “see-hear” things simultaneously as a “sum of sensations”. (Liljedahl, 2011, p.23-24.)

Despite the “multimodal whole” experience or the “democracy of senses”, we are able to distinguish the sounds from the visuals, and it is very common that sounds are considered to be more abstract. It is much easier to point out with visuals what the source of the sound is or what object the sounds are combined with. As Liljedahl puts it, “Sounds can also be said to be more ambiguous and leave wider space for interpretation than visual stimuli do, at least when it comes to interpreting where and what we have heard” (Liljedahl, 2011, p.25). Without the visuals, it is really hard to tell the source of the sound, unless we have a memory of the history or of the events that cause the sound, as was mentioned previously in the chapter of the listening modes. This is true for example when listening to a movie with your eyes closed and then watching the same scene again with the picture; what you imagined does not match the actual picture. Nevertheless, “Of both animate and inanimate beings, motion and sound, when paired, belong together. “Visualistically” sound “overlaps” with moving beings.” (Ihde, 1974, p.24.)

When the hearing is compared with the vision, “authors more often talk about ears and eyes than sounds and light” (Sterne, 2011, p.7). I have gathered a table based on the comparison between hearing and vision by Sterne. This comparison will help to use the benefits and disadvantages of both in order to create an effective sound design.

HEARING	VISION
Spherical	Directional
Immerses its subject	Offers a perspective
Sounds come to us	Travels to its object
Concerned with interiors	Concerned with surfaces
Involves physical contact with the outside world	Requires distance from the outside world
Places you inside an event	Seeing gives you a perspective on the event
Tends toward subjectivity	Tends towards objectivity
Brings us into the living world	Moves us toward atrophy and death
Is about affect	Is about intellect
A primarily temporal sense	A primarily spatial sense
Immerses us in the world	Removes us from the world

Figure 3.10 Hearing vs. Vision. Based on Sterne (Sterne, 2011, p.9).

In generative sound design with visuals, or with objects, or with anything indicating to visuality, it is utterly important to recognise which objects and visual stimuli will have a generative sound feature. Generative sound may not always fit every visual object or part. The generativity depends on the characteristics and behaviour of the visual object. In order to have a generative feature, the movement of the object needs to be either continuous or repetitive.

3.3.4 Sound functions in the interactive experience

In an interactive experience, the sound is bound to time, and in order to understand the way sound works with time, the force of it, and how it behaves in time “we have to grapple with how time shapes sound and how sound shapes time” (Franinovic&Salter, 2013, p.61). The time spent with interaction becomes the experience, it can be a quality time or not, depending on how the participant enjoys the experience. “The experience is controlled by a composition [that] anticipates the participant’s actions and flirts with his expectations” (Franinovic&Salter, 2013, p.61). As a sound designer, it is crucial to know how to flirt with the participant in a way that the experience is positive, because a negative experience always diminishes the quality of the work. Also the planning of the sound content in an interaction requires elaboration, because the participant always misuses the interaction, or tries to outguess the creator. All possible ways to interact should be acknowledged and their outcome heard. In generative sound design, the interaction testing is the mixing phase of the piece.

In the "Perceptual Evaluation of Sound-Producing Objects" study by Bruno Giordano, Patrick Susini, and Roberto Bresin, the event stages of sound generating objects are presented in a loop, where the motor behaves as the action, which then results after sound generation into acoustical information to the listener. Then, after the perception and cognitions, "the processing of sensory information will feed back into the planning and control of further sound-generating actions" (Giordano et al., 2013, p.153). See Figure 3.11. The study was consisted of four categories: psychophysical methods, verbalisation, continuous evaluation, and measuring of the acoustical information. This study is not the only one trying to answer the questions of sound with interaction affecting the experience through sonic means. The only way of finding out the exact experiences of the users/listeners is to arrange user testing with "various experimental methods" and "comparison tasks", and only then can conclusions be drawn according to the collected data (Giordano et al., 2013, p.172-173).

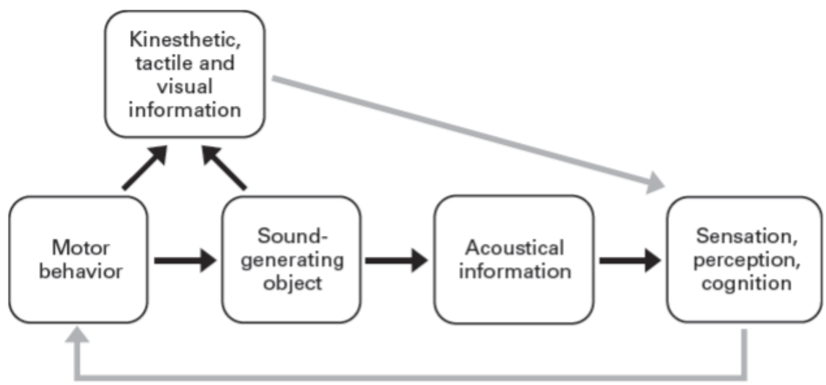

Figure 3.11 "Chain of events and processing stages involved in the perception and production of interactive sonic events. Arrows symbolize causal connection" (Giordano et al., 2013, p.154).

In the real-time interactive experience, the sound, the acoustical information, has multiple functions. The sound may function as a feedback, as a guide to responsive sound design, and/or create emotional impacts and immersion (see chapter 3.2.2 for immersion). The sound has to multitask, because most of the times one sound has several functions simultaneously.

The sound's function as a *feedback* is firstly meant to create the experience through emotions, as was stated previously; and secondly, sounds provide the feedback of the actions onscreen. Through feedback, the player will know how to react and interact with the game. The sounds can be immediate or subtle with a delay. The feedback information can be of many kinds, for instance, alarms to tell about danger and a certain situation in the game, or a sound for collecting an item, getting an upgrade, or reaching a save point.

In *responsive sound design,* it is possible to navigate the listener with sound, especially in a 3D world or in virtual and digital environments or installations (Beilharz, 2004). This responsive sound guiding will assist the listener and make the experience better. "By guiding the user with sound and providing feedback and responsiveness sonically, visual overload and cumbersome representations are avoided… The semantic connection between sonic and spatial experience imbues the generative sound design with meaning and comprehensibility." (Beilharz, 2004, p.2-3.) Although responsiveness and informative guiding are mostly used within generative sound design, it is not always needed nor does the sound design have to completely rely on the responsive actions. This naturally depends on the context where the generative sound design is being used. The responsive sound design is mainly used in games, in order to lead the gamer onwards or to the next step within the game. Beilharz has also listed the two most important tasks of the responsive sound design. These "primary purposes for responsive sound design are:

(1) to provide navigational cues supporting way-finding and spatial orientation; and
(2) to provide realtime generative environmental sound that reflects social behaviour in a way that is meaningful and recognisable" (Beilharz, 2004, p.1).

Also player-generated sounds in video games have become common. The player can customise the game, including objects and their sounds. This becomes challenging for the developers because the player has the "control over their intellectual property" (Collins, 2013, p.132). Then the role of the sound designer becomes even more challenging and requires more skill, if control is needed, and there should still be something that the player feels is customisable. This means the functions of each sound require more careful planning and require designing multiple sound alternatives, which still create the same emotions and fulfil the functions. However, it is certainly interesting how customisation affects the interactive experience and playing habits.

3.3.5 Another pair of ears and audio teams

Someone once told me that one iteration after another and having test users always helps to develop the sound quality further. It might be deceiving for the sound designer to only rely on his/her own ears. A test run or a test listening will discover the features of the sounds that immediately stand out. Because sound design for interactive and more generative systems is much harder and requires more time, the game companies have created sound quality assurance methods to ensure the sound behaves and plays in the game as intended despite of the many ways the game could be played through.

In game companies they call this the active listening phase, where the game is played over and over again in order to find mistakes, bugs. After noticing the bugs or remarks in the game, they denote them with their own application systems, in which these bugs or notions can be put on a record list. This list can be seen by all of the people working on the game, and especially the audio team. From there, they can see the exact places where the bugs are in the game, and therefore they are easier to find again for fixing. After the bug or missing sound has been fixed, the mark will be checked off. To do this, sometimes a certain person is hired to game companies to work as an audio assurance (QA) or audio tester. However, testing is also done by the entire audio team members and especially towards the end of the game building. "The audio quality process is a combination of many parties. The audio director sound designers themselves pay attention when designing and implementing sounds and when test playing. Quality Assurance departments also test the sound and give feedback. Any developer working on the game may have ideas or feedback for the sound." (Hajba, 2015.)

The audio teams have several people working on different tasks with the sound in order to ensure the quality of the sound in the game. In most game companies, the in-house audio positions in audio teams are divided according the following figure 3.12. Some companies might not have audio teams at all and only use freelance sound designers or another company that provides the game audio for the game, or have the in-house audio team work hire outside the company in some instances to work on specific sounds. I believe all these factors affect the sound quality; an effective and well working team surely secures the quality of the audio. The audio teams in game companies will soon reach the amounts of working audio personnel in films.

Title	Work description
Audio Lead / Director (Director of Sound) (Technical Audio Director)	The person who oversees all audio aspects of a given game project. His/her responsibilities include overseeing all assets, as well as defining the schedule. (The person who is in charge of the entire audio division within a game company.) (This person analyzes, defines, and informs teams about their audio pipeline, including tool choices. This is sometimes a responsibility covered by the Director of Sound.)
Senior Sound Designer / Sound Designer / Junior Sound Designer/ Sound Assistant / Intern (Sound Event Designer)	The person who creates the actual sound file assets that get implemented into the game engine. He/she often works from a spotting list and schedule. (The person who defines the events and states to which the dialogue system will respond to. These events typically provide content for the voiceover recording scripts.)
Recording Engineers (Dialogue, Foley, Field)	The person who specializes in recording sounds in a studio or on location. He/she has understanding of microphones & placement, pre-amps, and acoustics, and how they relate to achieving good quality recordings; and he/she creates recordings that can subsequently be utilized further down the chain.
Mixer	The person who takes the finished sound assets and mixes the game & cinematics for final delivery.
Procedural Sound Designer	The person who designs the granular or particle type sound effects recombinant playback system that reacts to various parameters in real-time. He/she may or may not create the sounds himself/herself.
Audio Programmer (game play/tools/engine)	The person who adds the audio engine to the overall game engine, as well as creates and maintains the event and data calls between them. This person supports the audio team members with pipeline issues, and acts as a liaison between the audio team and the programmers in order to provide necessary tools for audio production.
Audio Tester / Quality Assurance (QA)	The person who play-tests through the game in order provide feedback to the audio team so they can ensure a quality soundtrack.

Figure 3.12 A list of Game Audio jobs with descriptions and desired skill-sets provided by Project Bar-B-Q (AES, 2009).

3.3.6 Sound design challenges and quality loss

It is always important to remember when designing something interactive or generative with sound that there will be a definite quality loss in the sound design irrespective of the output of the sounds. This means the sounds will not sound as intended or imagined through different setups of speakers or headphones. Therefore the design should always be made in a way that it will sound good no matter what the output technology is.

When designing a generative sound design with interactivity, the design needs to take certain practical aspects into consideration, because "nothing looks worse in an exhibition than a blank screen or sounds worse than a silent loudspeaker. In the case of interactive works, accessibility, simplicity and reliability are essential aspects of success." (Gibbs, 2007, p.107.) The technology should be as robust as possible; and this technical execution is also a matter of the design. Every part of the design from the idea to the actual output of the sounds should be designed not only in theory but most importantly in practice. It is always good to design in a way that the designer places himself/herself to the role of the user or listener.

Financial effects to sound design quality always affect the quality, and sometimes with a huge negative impact. If the sound design does not meet the visuals with the quality comparison, the visual might suffer a huge drawback in perceived visual quality and overall quality of experience. "Continuous interaction also poses risks to design if the implementation is clumsy. The Midas touch problem is that if every action creates audible feedback, people can rapidly become irritated and are likely to reject the system. Appropriate natural methods for "decluching" the audio feedback are likely to be critical to acceptance." (Visell et al., 2013, p.93.)

The limited ways of our hearing and perception create an observation bias in detecting the pitch or sound location and the difference from the actual physical sound behaviour. For instance, "a short sound repeating with chopped intervals and playing from different locations will be interpreted as the motion of the sound" (Aro, 2006). This is why our ways of perception are still vague and unreliable to some extent. Nonetheless, I believe that this observation bias can be used as a benefit to increase the quality as long as the observation bias proves to be perceived in the "wrong" but the same way by the listeners.

In addition, "Noise distracts the attention" (Bijsterveld, 2006, p. 153). What is perceived as noise will distract the listener from the actual design and content. Unwanted sounds are normally perceived as noise. These unwanted sounds vary by the listener and are also hard to detect. However, outlines in studies have proven that the traffic sounds are often perceived as noise and sounds of nature as relaxing and wanted sounds.

3.3.7 Discussion about sound design quality

According to the majority of the interviewed professionals, sound quality has two obvious definitions: a technical and an emotional quality. Obviously, the sound design quality has to be technically good, but the main focus is to achieve an emotional experience. "Sound quality is mostly technical. It can mean the fidelity (bit depth, sample rate), the surround directionality, the available polyphony, even the quality of the hardware the sound is played from. Sound design quality is the measure of how well the sounds are implemented within these technical limitations, and how well they fulfil their purpose of communicating to the player." (Hajba, 2015.) However, many pointed out that low-fidelity sounds may also be used depending on the design and which sounds would be best for it. Thus, the creativity in the sound and the emotional impact are much more important than the technical aspects. Some said the technical aspects do not matter, because the technical quality is overall very good nowadays. "To the free creative approach of the sound, the technical tools hold no affect to the sound itself" (Görne, 2014). Therefore, the attitude towards finding the perfect sound may not necessarily lie on the fact how well the sound was technically created in the first place.

When the interviewed were asked what kind of sounds are of a good and of a bad quality, their answers varied from emotion, meaning, creativity, and context to many others. However, according to many, good/bad quality is connected to a feeling or an emotion. "Quality sound will somehow create a shift in my thinking on my emotions or something. It'll inspire me, It'll cause me to be creative as opposed to downing quality; bad sound will have the opposite effect. It will basically push me away instead of drawing me in." (Nielsen, 2014.) If the sounds are bad, they very easily start to irritate. "One of the very first rules is: do not annoy. If the sound annoys the player, it should not be there, should be brought down or redesigned." (Hajba, 2015.) Thus, instead of negativity, a positive feeling is preferred. However, it was clearly important to the interviewed that the sounds should evoke any feeling, and with success, the sounds will become of a good quality. "A good sound to me in terms of sound design is something that will and should provoke something in you. Something that you can picture, something that you can smell, something that you can feel, whatever it is. That is good sound design, it means that there is something, there is a meaning. It is not just frequencies." (Deriviere, 2014.) If the emotional connection is not clear or the sounds do not fit the purpose, the sound design becomes bad; it fails to do its task.

Not only do the emotional aspects of the sounds have the primary importance according to the interviewed but also the narrative, the context, and the story. Everyone agreed that the sounds designed need to fit the context; this was a common line throughout the interviewed. "I look at quality of the sound in relation to the context. A pixelated arcade game would benefit from other sounds, with other quality than say a romantic play for digital theatre." (Nispen, 2014.) If the sounds do not fit the context, it has a direct impact on the experience of the entire design. "Sound has so many subtleties that when it comes to quality it probably can be summed up with accuracy reproduction, enjoyability, and intelligibility" (Ciceri, 2014). Almost everyone made a remark that the sounds need to be plausible, believable within the context. "I think that at the end of the day, all of the work that we do has to be believable. When I am making a creature or when I am making anything that does not exist in nature, it only works if it is believable. Whether it is generative or procedural, the ultimate goal is that it fits on screen with whatever I am adding it to. Good generative sounds feel natural, they fail if they don't fit." (Nielsen, 2015.)

A good sound design was clearly an artistic process to all of the professionals, where the designer needs to understand the relationship of the sounds to the other aspects and parts of the work which the sounds will be designed for. "For me sound designing is like writing poems or creating a poetical relationship with the different sound elements and the audience. For me it is very important that I address the whole imagination that implies the whole body of the audience, the whole corporeal experience of somebody. So sounds are very much related to tactile sensations, to kinetic sensations, to smells, to lots of other things, of course visual references, actions, everything you deal with within the world." (Decoster-Taivalkoski, 2014.) Overall, a good sound design should consist of good quality sounds that fit their purpose and context, and have the main idea of the entirety. Even so, many of the interviewed said that a good sound design is something that the listeners will not notice.

This old statement about good sound designs is something that has been among the sound design professional as the advice to good sound design for a very long time, and if the sounds are noticed then something must be wrong. Luckily, in the game industry, the thought of the wow-factors has spread out, and some moments of "sound success" are actually wanted. "Often it seems like, if the sound designers do their jobs right, nobody will notice a thing. But there also needs to be some "wow, that's a really cool sound" moments." (Hajba, 2015.) As we pondered with Joonas Turner whether this statement was already outdated, we came to the conclusion that maybe the sounds should be noticed in some ways as more positive, that they should impress, and even if they would overpower sometimes, at least then the experience would have a different kind of boost, a personality. As Turner states, "Nowadays we have equipments to do crazy good stuff and now if no-one notices it is like fine, but it does not bring anything to table as well. Why not aim for: Hey, I wanna bring something new to this experience!" (Turner, 2014.)

The sound space was also mentioned by the professionals, as it is a very essential sonic characteristic, and for sound installations the space is one of the most crucial aspects. “Sound installation for instance I particularly hear in a way that the sound is a space and a landscape, for me a good sound design is something that brings you into different spaces, it makes you sense that you can dive into something” (Moreno, 2015). When we talked about the important factors of space in relation to the sound quality, Josue Moreno also added that the sounds in a space should generate a discussion between the space and the visitors and that the emotional relation with the space and the sound itself is required. It was also mentioned by others that the sound has remarkably important spatial qualities, which also require designing with respect to the context.

The generative sound design has to mainly fill the requirements of a good sound design, but is there more to it? Many of the interviewed said that there is not much of a difference when evaluating a good or a bad sound design compared to a good or a bad generative sound design. It is hard to evaluate something that might not be recognisable for the listener, and the implementation is a process the listener is unaware of. According to Marianne Decoster-Taivalkoski this could be the design of the cleverness in the system, like beauty under the hood. “There is probably some kind of aesthetic thinking or how the system is built in itself that you cannot hear. It has to be clever in a way that it is producing sounds that are fitting the role in the sound design.” (Decoster-Taivalkoski, 2014.) This could be the beauty of the sound behavioural design, the design behind the sound design, and if the behaviours are designed well enough, it should enhance the experience. The quality in the design of the system is directly verged to complexity. “The creator makes the mistake of assuming that the complexity of their process is somehow connected to the complexity of the listening experience, and I think it is not. The most complex sound design often seems so simple that it is largely invisible.” (Andean, 2015.) Other interviewed also made some remarks about the intelligibility of the design in the system; maybe the beauty in the system could be how clever it is.

While quality is mainly behavioural in generative sound design, the possibilities to fail with the design are also mostly caused by sound behavioural problems. Especially in games, the sound quality is tightly attached to the interaction and functions of the sound. When the generative sound design simply fails, it has crucial impacts on the mood of the player and the experience. It may even ruin the flow of the game play. According to game sound designer Peter Hajba, badly designed game sounds may tend to:

- “conflict with each other for attention
- irritate the player by sounding harsh or being annoying
- be unrecognisable for what they stand for (the player goes, “what is that sound? What does it mean?”)
- be too long, cluttering the mix and eating up polyphony with their long tails
- be either too prominent, or too unnoticeable for their purpose
- instead of providing good feedback, may even mislead the player” (Hajba, 2015).

Many of the interviewed also said that the quality is the end result, the final outcome. Therefore, some commented that everything done before the final outcome is actually a part of the quality process, including the terms or tools of complexity and realness. “Complexity is a part of quality. Quality is sort of the end result. Realness and complexity are sort of in a way of tools on the path to creating quality. If quality is the end goal, and for me it is, because to me quality is like full transmission of information and emotion, then quality is the measure of that success. Complexity is one of the tools to accomplish that. Realness is an aspect of trying to emote something in the viewer. I would think of them as components of quality." (Nielsen, 2014.) The sound design quality process was something that was thought of as a very broad action, as it would include all from technical aspects to the narrative and everything in between. The process itself to the professionals in their own works was mainly an intuitive thing and came by itself as a natural part of the design process. Overall, the quality could only be only evaluated as the end result of the design and its experience.

3.4 Conclusions

When designing generative sound design, the quality of it can be assessed with several tools, and with technical and emotional aims. Realness and complexity can be thought of as methods to develop the design to the level of being a quality experience, execution, and outcome. The result of the entire design can only be assessed together with all the aspects afterwards, as what we perceive can only be analysed after the experience as quality.

A complex generative sound design is based on sound quantities, sound grouping and layering, and because the process is non-linear, it requires many simultaneous sounds, sound textures, groups, and layers. Also, the manipulation of the sounds will happen in real-time and requires the knowledge of programmable sound manipulation and modification. The usage of the parameters is also very relevant in an interactive generative sound design. Most importantly, one of the core elements is to avoid easily recognisable repetition and to utilise masking and overlapping in the sound outcome.

The sound complex is parametric and technical, which makes it a process for the handling of the sound. It is a meta-design including manipulation of the sound behaviour. By understanding the need for the sound to behave in a certain context and by sensing this need as the complexity, it will result in realness and onwards to emotions, and immersion. This behaviour is something that affects all the other aspects of the design as well; how the sound behaves in reaction to other elements. If the behavioural acts are too complex, it may be destructive; it may ruin the experience, which is why the sense of sound complexity is required. Having the sense of complexity is like having good ears with sound.

While the battle between procedural and recorded sound somehow continues, they have learned to co-exist due to sound designers realising the advantages and disadvantages of both. Even if there are strong habits in the way of creating and working, these both will surely go hand in hand also in the future. Organic or synthetic sounds are always chosen by the context, it is mainly about the feeling and the atmosphere that the sounds create. Thus, the plausibility resulting in immersion can be achieved by both. Even if the sound is not real in real life, the listeners will accept it, if it feeds their dreams and fantasies, and intrigues their imagination. I believe that both of these sound formats are needed, and with their combinations, the designers can create something extraordinary.

When it comes to the visual quality affecting the sounds and vice versa, it is good to remember that it is much easier to trick the eye as a visual illusion than it is to trick the ear. I would say that sonic recognition is strong, because the brain knows when the sounds are sounding right or wrong. Maybe because of this, the sound origin has become an issue. The sound chain reaction with the narrative, emotions, and immersion is not simple with sounds that do not fit or do not sound real. It might be that the breaking of this chain is still the main issue with procedural sounds.

The flow in this process is the result of well designed interactivity. The interactivity is created as fluent and natural as possible. When the interactivity is clear, it enhances the quality, while the focus and the attention are not disturbed by other factors than the sounds and visuals creating the emotional mood. Only then will the sounds fully do themselves justice and reach quality as an end result.

Quality can be created with emotion, meaning, context, and enjoyability. The generative sound design requires different tools to achieve this. Generative sound design has the full potential to create new quality experiences and possibilities to compose strong events. The more generative, the more unpredictable the sound design becomes. This unpredictability will make the experience more thrilling, surprising, and exciting, therefore enhancing it. I have gathered the quality enhancing factors and quality loss factors for generative sound design quality in the following figure 3.13.

Enhancing factors	**Quality loss factors**
Good technical quality	Bad technical quality
Emotional impact	Too complex
Plausibility, believable	Misleading
Sound connectivity to other aspects	Unfitting
Narrative, story	Irritating, annoying
Idea in the design	Sound conflict
Sound behaviour	No emotional connection or wrong connection
Clever system design	Repetition
Invisibility	Unclear sounds or noise
Wow-moment sounds	Has no function
Another pair of ears	Bugs in the game play
Aesthetic connection	Masking
Freshness, always changing	
Flow in the game play	
Masking	
Variations, sound quantities	
Immersion	

Figure 3.13 Summary of generative sound design quality factors.

When the sound is wanted to imitate the behaviour of a sound in real life, it is the complexity which creates the realness, and the realness creates the plausibility, which then results in immersion. This part becomes the in-between of narrative and emotions, and the final outcome is when the experience becomes enjoyable, and the amount of enjoyment measures the quality (see figure 3.14).

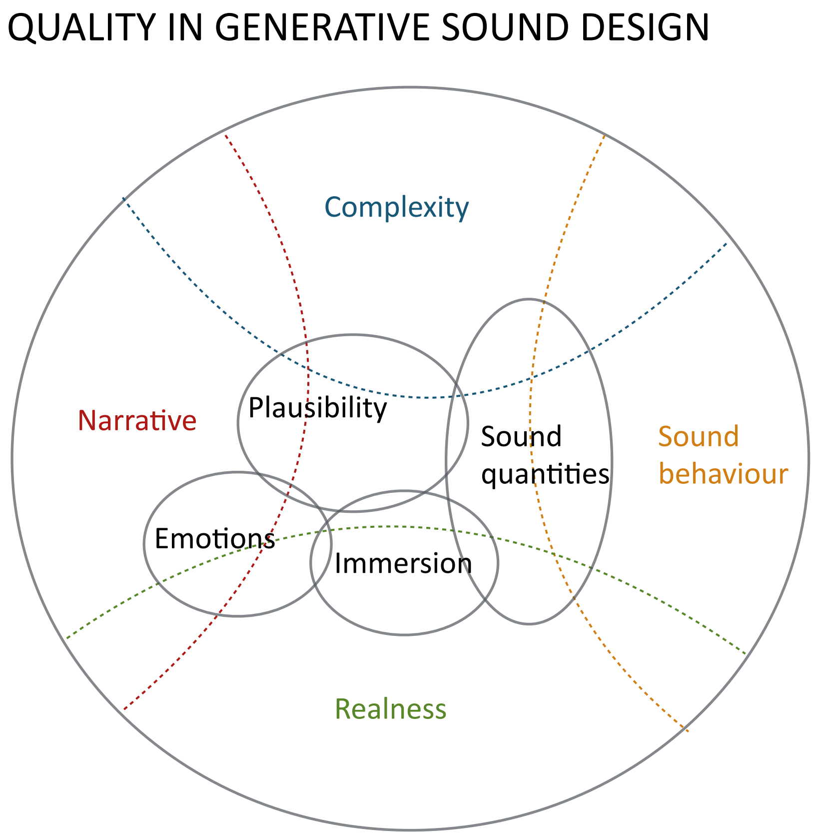

Figure 3.14 Generative sound design quality relations.

Even though the technical and emotional qualities of sound are in symbiosis, lacking in either may make the design fail. The emotional side can be thought of as more effective. An effective sound design leads to good results: the listener understands the heard sounds. This aim for purpose will give the sounds an idea, the design has a flow, and the final outcome is aesthetic. These quality aesthetics in the sound design could be (1) the design of the sound, (2) cleverness in sound behaviour, and (3) sound affecting visuality.

4. Case Study 1: An interactive 3D environment sound research

I wanted to know whether people would notice sound generativity and the difference in sound quality during an interactive experience. If they would notice something, I was eager to know in what way and what would result from their reaction. Therefore I planned to create two different sound designs to a single virtual environment. These two sound design experiences would then be played by the test users and their experiences compared. In order to have equally comparative results, it was crucial that the two sound designs use the same sample sounds. The other sound design would be generative and the other non-generative within the same environment. To increase the differences in these two sound designs, I decided to also add a sound quality factor to the comparison. Consequently, the non-generative design was compiled with uncleaned and unedited sound samples (low quality) and the generative design with the same sample sounds as edited and cleaned (high quality).

The 3D environment was created by Alexander Nikulin, who is a game designer and a PhD student in Game Design at Aalto university, particularly for this user test by my request. He used the Unity game development platform with the Playmaker visual scripting plug-in. As the audio engine in the environment, I decided to use the FMOD Studio, since there are no restrictions to use it with the Unity free version, and because I got an opportunity to use the procedural plug-in AudioWeather, which unfortunately later proved to be incompatible with Unity.

The aim was to create a simple environment with a short route, which would be as easy as possible to navigate for the test users. The environment was meant to fit both generative and non-generative sound sources. For navigation I chose a game console controller, and in order to minimise the attention used for navigation, there would not be any button triggered interactive actions by the user; instead the users would be only moving forward in the environment.

4.1 Planning the 3D environment, a generative game sound space

The 3D environment is located on a swamp with a route that the test users will follow. The route consists of wooden shacks, piers, rocky paths, and stairs from the swamp towards the top of a small hill, where the game ends. A sphere of light, a pixie, guides the user along the route where there are few objects, such as a door, a cloth, and a lantern, which the pixie hits while guiding the user to go forward. Other objects, such as ceramic bells hanging on a rope and small cloths on the trees are also located on the route and fluttering in the wind. The water in the swamp ripples and the grass swings in the wind. The ambience of the environment is quite gloomy and cloudy, and the player also triggers at the halfway in the environment a rain with thunder (see figure 4.1).

Figure 4.1 The starting screen of the 3D environment; a swamp with a route, and the guiding sphere of light (pixie).

On the route of the environment, the player would interact by triggering events in seven places; the most noticeable ones are when the player enters a trigger area, which are located in front of a door, a cloth, a lantern, and at a wood shack. There are three triggers which make the pixie fly and hit these objects with a sound. At the wood shack the pixie floats until the player triggers it to move forward to the end area. There is also a trigger for the rain and thunder to start and stop, and also a trigger at the end which ends the game. The planned route is shown in figure 4.2.

Figure 4.2 The route of the environment looked at above in Unity scene developer.

The objects in the space were designed to have a constant animation and therefore constant sound. It was important to have constant different sound objects in order to implement generative sound features into the generative sound design of the environment. When navigating in the space, the player would also have the sound of the footsteps. All of the different surfaces would have their own footstep sounds. In order to do this, a surface mapping of the game area was made. Because the attention of the player is mainly focused on the pixie throughout the environment, it became the most important sound. This definitely needed a sound which could be made generative. I also wanted this sound to be synthetic in order to find out how people will react to it.

4.2 The making of the two different sound designs for the same environment

When I started to plan the sounds, I created a list of the sounds needed. According to the list, I started to "hunt for the sounds", in other words searched for places where to find the sounds and record them or searched for sounds which would fit the environment from different sound libraries. Recordings happened in several locations, although only some of them I found perfect for the environment. About half of the sounds were recorded at a Foley studio.

I gathered all the sounds into a folder system, which I had created for the editing process and for the categorising of the files. The first folder would include all the sounds as raw material that I thought would fit the environment. The second folder would include all the selected sounds, those that I would actually use in the environment. The third folder would have the sounds as edited; this folder was split into two designs, the sounds without processing for the non-generative design (SD1) and processed sounds for the generative sound design (SD2). Then the edited files would be converted from .wav format to .ogg format for the final Master folders for each design (see figure 4.3). The .ogg format is most commonly used in games because of its lossless audio compression.

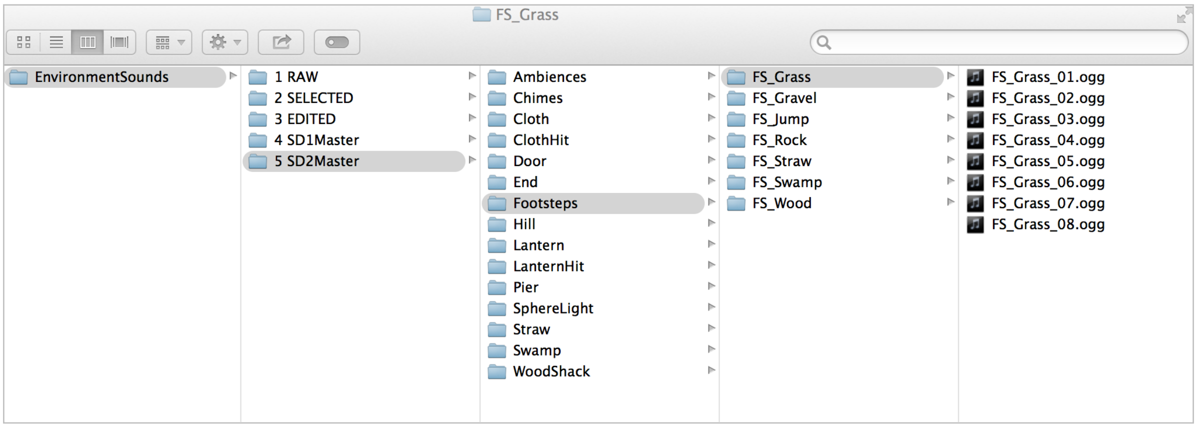

Figure 4.3 Sound design sample filing for the designs.

I created only one FMOD Studio session into which I added all the sounds from the master folders and created all the sound events needed in the environment. After completing the design as generative with all of the most complex features, I copied the session and created the non-generative version by only deleting all of the generative features and by replacing the sounds with the SD1 versions. It was much easier to create the complex version first and basically downgrade the other version.

4.2.1 Sound design 1: Simple design (non-generative)

Sound design 1 (SD1) was created with sample sounds with short sound loops and with non-processed sound files. The sounds were basically taken from raw recordings and edited as short clips. I consider the quality of these sound files to be low, because the files were not cleaned, and the recorded noise floor was not removed, and the files included all the original frequencies without any equalisation. The sounds were only made as short repeating loops or as short clip sounds for the triggering.

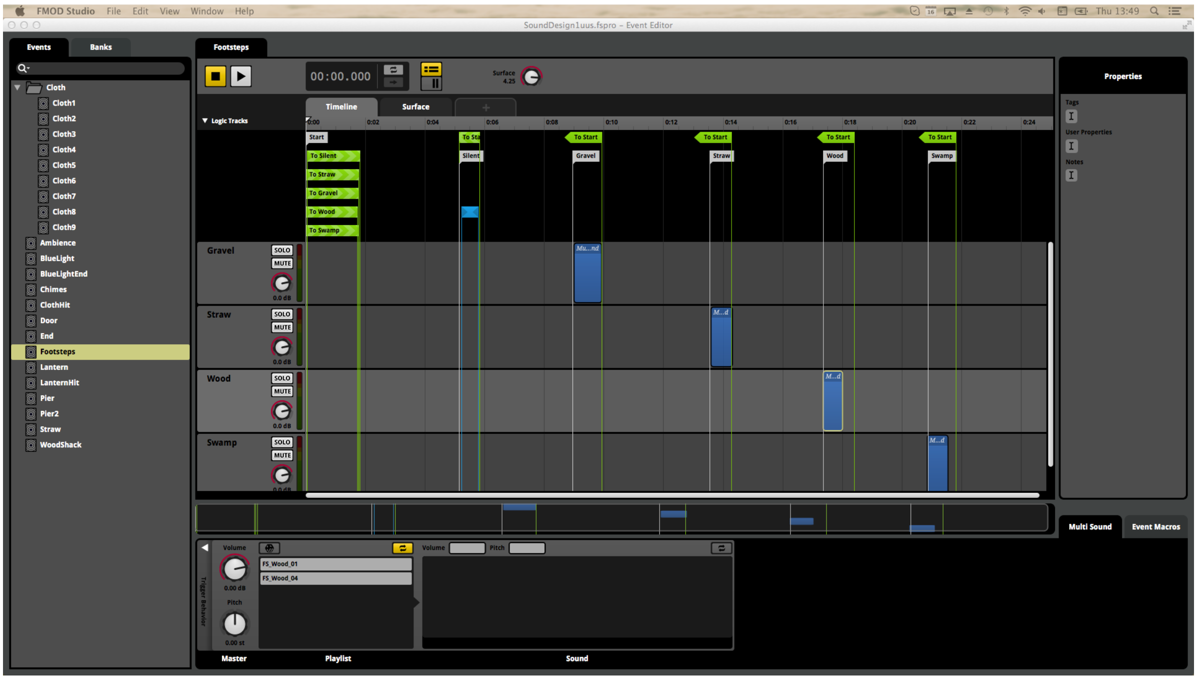

Figure 4.4 Sound Design 1 in FMOD Studio, footstep sounds with only two sample sounds repeating for each surface without modulation.

The sound variation was made as low as possible, each object would only have one sound. The only exception was the footsteps, which had two sounds repeating one after another on each surface: two sounds for wood, two for water, and so forth. All the hanging cloths had the same sound. The pixie also had the same sound repeating as a short loop every time it appeared. Also there was only one wind sound for the entire area and two bird sounds repeating one after another. The water ambience was also repeating on the background as a short loop. None of the sounds had any generative modulations or randomisation, the volume and pitch were all static. The sounds were simply played as they were in their original form.

4.2.2 Sound design 2: Complex design (generative)

Sound design 2 (SD2) included long loops and cleaned sounds. All the sounds were cleaned with the iZotope RX4 audio repair and enhancement software. “Cleaning” in this context means taking out or filtering frequencies and parts of the sound that are not needed or are making the sound unclear, such as hums or other noises. I removed the noise floors, took away all the far high and low frequencies with equalisation. All the unwanted noises, clicks, and pops were removed and equalisations were made for the sounds to take down annoying frequencies and to make the sounds more pleasant.

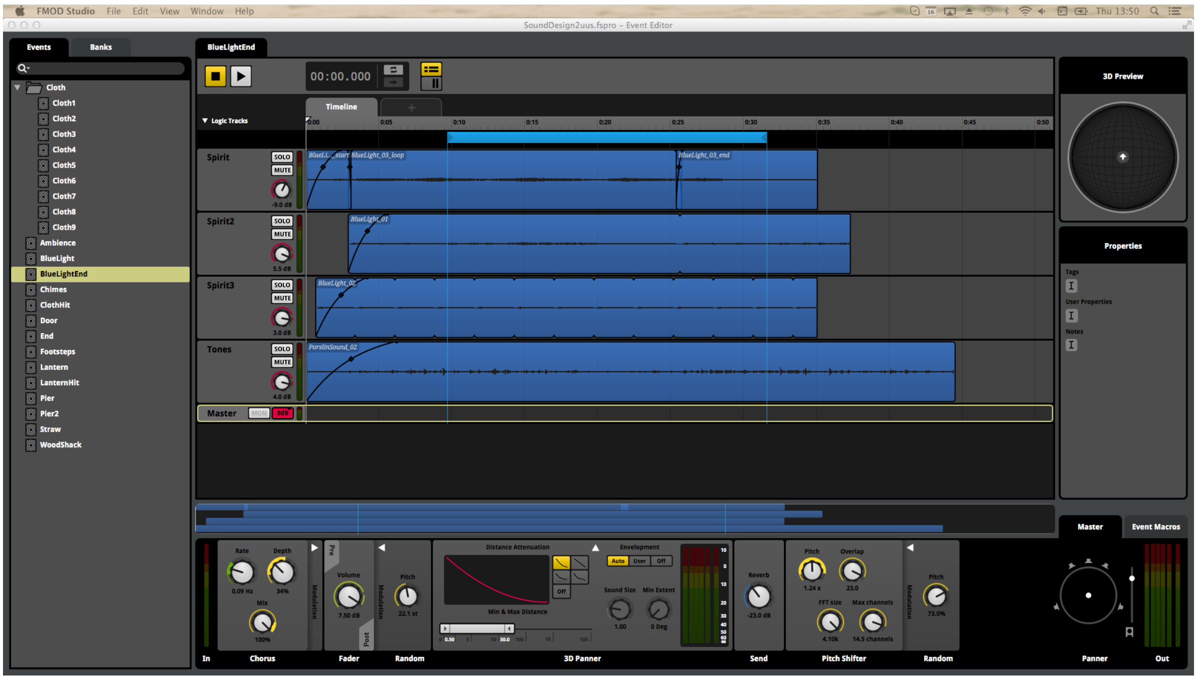

Figure 4.5 Sound Design 2 in FMOD Studio, the light sphere (pixie) with random modulations.

The generative sound design included sound variation, and the audio system also generated variety with the amount of sample sounds. All the footsteps on different surfaces had variations; one surface had eight different footstep sounds. These where randomised with order, pitch, and volume. Therefore there were multiple variations of all these eight sounds per surface. All the hanging cloths had their own sound and the sound loop was significantly longer. Instead of one sound, the bells had two sounds playing simultaneously with different length in the loops. The pixie had the same sound loop but instead of starting from the loop, there was an intro and outro for the sound. These sounds also had random modification in pitch, pitch shifter, reverb, chorus, and with modification fader adjustments. More bird sounds were added as a scattered sound event with a defined interval between randomised play of the bird sounds, with a maximum polyphony of 3 bird sounds playing simultaneously. The bird sounds were also randomised in pitch and volume. At the end of the game, where multiple pixies were flying, I had multiple different sound layers of pixie sound playing. They were all modified with several different harmonisers and effects. In the non-generative design, there was only the same pixie sound loop. The ambience sounds were also longer loops, and there were three different kinds of winds, one wind for the swamp area, one for the hill area, and one howling when the player was next to the wood shack. The wind had random volume automation, which made the wind sometimes come louder and sometimes more subtly. The water ambience also changed depending on whether the player was close to the pier or an open water area.

4.2.3 Comparison of the sound designs

The biggest differences with the two designs were that the sound design 1 had uncleaned and the sound design 2 had cleaned sounds. The loops in the sound design 1 were extremely short and in sound design 2 significantly long. In the sound design 2 the generative sounds were the pixie, footsteps, and birds. See figure 4.6 for the comparison of the sound designs.

Sound	Type	Action	SD1 variety	SD2 variety	Sample	SD1/SD2 editing
Door	Single sound	trigger	1	1	recording	unclean/clean
Lantern hit	Single sound	trigger	1	1	recording	unclean/clean
Cloth hit	Single sound	trigger	1	1	recording	unclean/clean
Lantern	Loop	constant	1	1	recording	unclean/clean
Cloths	Loop	constant	1	9	recording	unclean/clean
Rain	Loop	trigger parameter	1	1	recording	unclean/clean
Wind	Loop	trigger parameter	1	2	recording	unclean/clean
Water	Loop	constant	1	2	recording	unclean/clean
Grass	Loop	constant	1	2	recording	unclean/clean
Light sphere (pixie)	Loop	trigger	1	uncountable random (2)	synthetic	-
Pier	Loop	constant	1	2	recording	unclean/clean
Wood shack	Loop	constant	1	2	recording	unclean/clean
Chimes	Loop	constant	1	2	recording	unclean/clean
Footsteps	Single sound	trigger parameter	2	uncountable random (8)	recording	clean/clean
Thunder	Loop	trigger parameter	1	1	recording	unclean/clean
Birds	Scattered sound	constant random	2	uncountable random (5)	recording	unclean/clean
End sound	Single sound	trigger	1	1	synthetic	-

Figure 4.6 The functions and differences of the sounds in the two designs.

4.2.4 Implementation

The implementation of the sound design with the Unity engine was not as simple as I had thought. The actual integration with FMOD Studio and Unity was easy, but there were little or insufficient tutorials for combining the sound events from FMOD studio to the game engine, especially when using PlayMaker for the creation of the game tactics. I was not familiar with the Unity PlayMaker but soon learned how to activate the sound triggers with it.

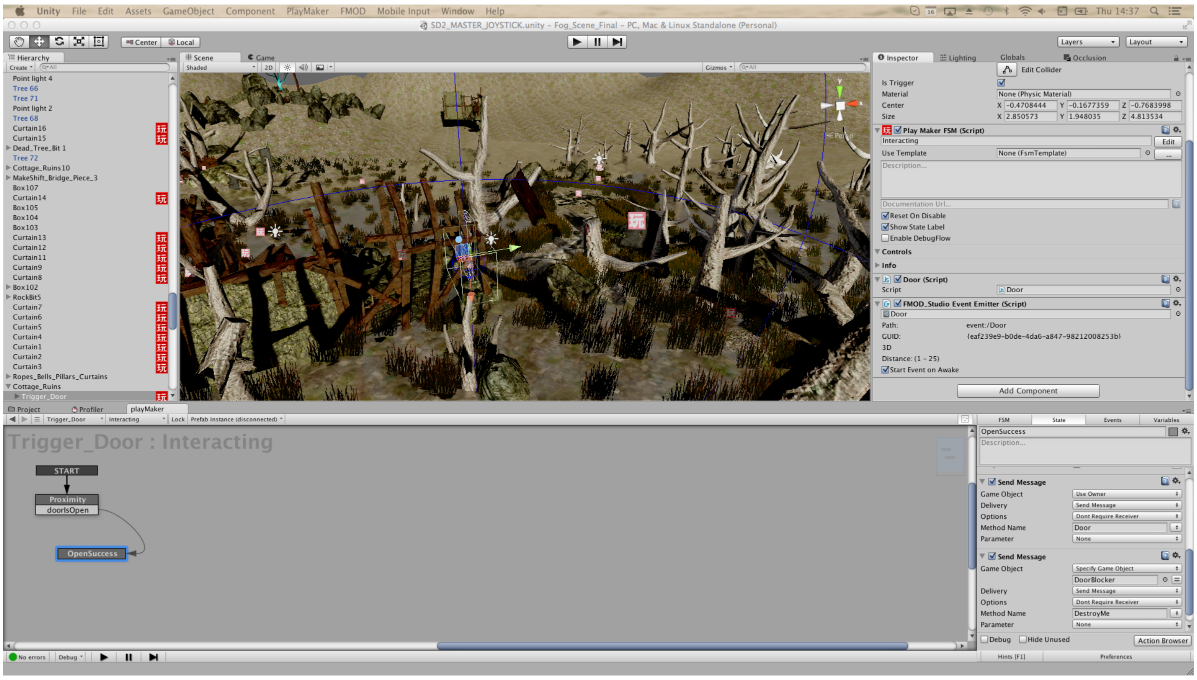

Figure 4.7 A door sound object in Unity and its script to FMOD triggered with a PlayMaker message.

The sound programming in Unity was easiest to keep the same for both designs. Therefore all the changes of the sounds were made only in the FMOD Studio by making the two sessions different. When building both games, I only needed to bring the GUIDs and build files from the FMOD Studio sessions to the game and create first the SD1 as the non-generative game application and then SD2 as the generative game application.

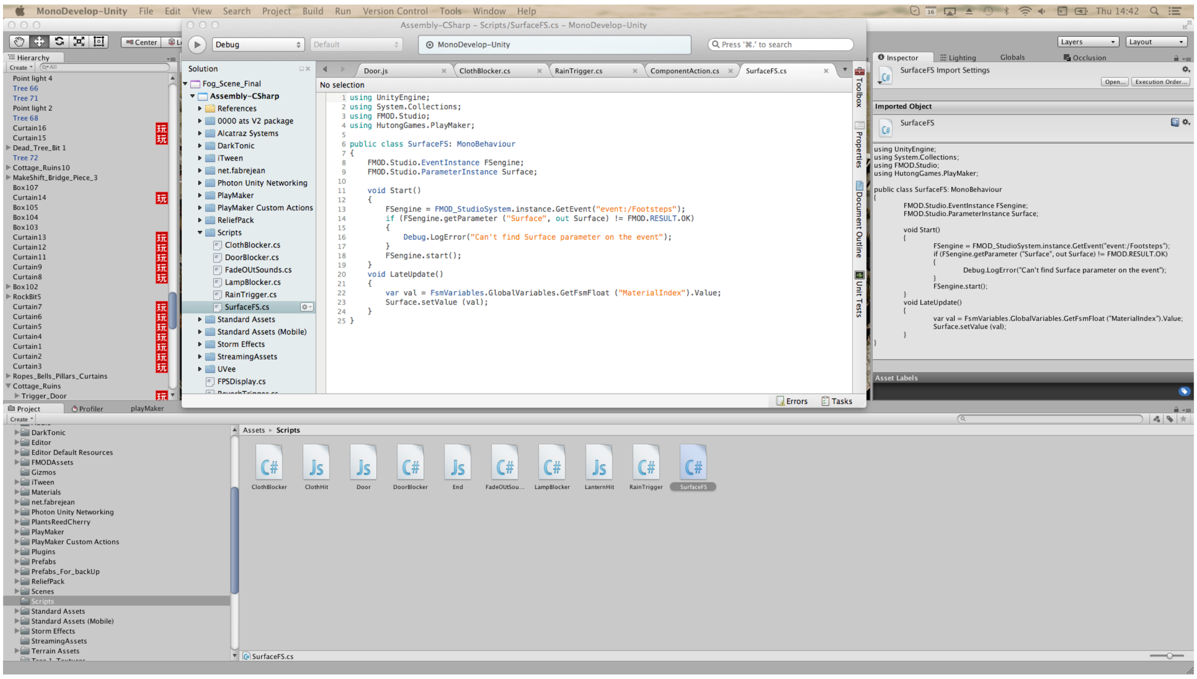

Figure 4.8 Footstep sound programming with C# between Unity and FMOD Studio.

The sound triggering of the game events was programmed either with JavaScript or C# scripts. The message of the player's actions was sent from the PlayMaker to the script, which would then play the sound event. In Unity I was able to also see how far the sound would stretch as 3D, and then I could adjust how far the sound of the objects could be heard by the player.

The controls with the Xbox One controller were programmed to the Unity engine. To get the computer to detect the controller, a Xone controller driver was required, and then the Unity identified it as a controlling device (see page 75, figure 4.14). To get the controller to work with the footstep sounds according to the surface identification made with the PlayMaker became technically challenging and some bugs were left in the game because of these technical difficulties. For instance, the sound of water footsteps would continue to be heard even when walking on wood, if the player did not stop at all and kept walking continuously. These bugs with the footstep sounds were unfortunately easily spotted by the test users.

Originally, for the wind sounds, I wanted to use the AudioWeather generative plug-in integrated with the FMOD studio, but in order to use the plug-in in the final build of the sound design and in the game, the plug-in requires purchase. I contacted FMOD and they provided me library files to be implemented into the game engine. After some problems of trying to get the files to work in the environment I found out that Unity only supports the dynamic libraries of AudioWeather, which are not currently available from FMOD, and that FMOD had provided me static library files, which can only be implemented to game developers' own engines or a UE4 game engine. Therefore I was not able to include any procedural sounds to the environment, which was a huge disappointment to me. If I had known this earlier, it would have most likely pushed me more towards the use of Wwise as the audio engine.

4.3 User test

The research test took place at Lume Sound Studios (Äänimaa) in Hämeentie 135C, Helsinki, at the Aalto University. The testings were held between the 9th and the 14th of July 2015. The test room was a sound proof studio recording booth, which I had transformed into a testing space with a screen and a Genelec 8030A speaker set as stereo next to the screen. The navigation in the game was controlled with an Xbox One controller.

Figure 4.9 Test space at Lume Studios.

I triggered the game from my laptop onto the screen in the studio space next to the booth, when it was time to play the environment. The answering to the questions happened online on another computer also in the studio space next to the booth. My intention was to make the playing in the booth as comfortable as possible. Test users also got candy during the test, but the majority chose to eat them only after the testing. Some did not even want any candy, because the playing and being part of the research test was enough fun and excitation for them.

4.3.1 Test users

With the help of an advertisement in the social media and a Doodle calendar booking system, I was able to gather 36 people who came to do the test. In total 40 had booked a time, three people did not show up on the booked time and one cancelled. These test users were from several nationalities and mainly living in the area of Helsinki and Tampere, Finland. There were both males and females between the ages of 11 and 54, 21 males and 15 females (see figure 4.10). There were some users that had no experience of games or interactivity, and most had no experience in sound, but there were also some who were experts in all these fields. The test users' experience of playing games was included to the background in games, and the background in interactivity meant skills for more use and development of interactive software than for example using Facebook or similar applications. See figure 4.11 to view the background skills of the test users. Most of the test users had not been involved in an academic test before.

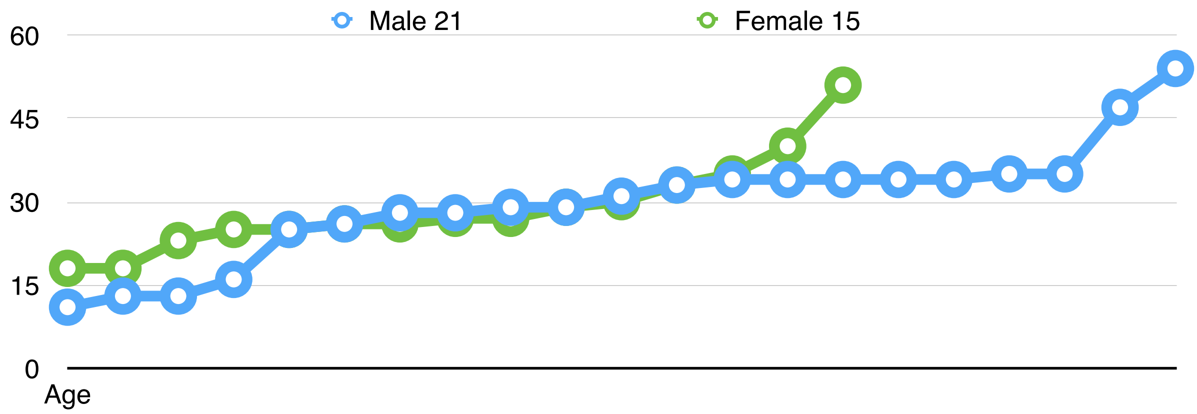

Figure 4.10 The ages and genders of the test users.

	No background	Beginner	Some skills	Skilled	Expert	Total	Average	Median
in sound	16	4	7	4	5	36	2.39	2
in games	3	14	10	6	3	36	2.78	3
in interactivity	5	9	12	7	3	36	2.83	3
Total	24	27	29	17	11	108	2.67	3

Figure 4.11 The background skills of the test users.

The test users said that they pay attention to the sound in games more than average, where 0 was not at all and 5 a lot. There were some people who did not really play games, but when they had played games they had paid attention to the sounds (see figure 4.12).

	0	1	2	3	4	5		Total	Average	Median
Not at all	0	1	8	9	11	7	A lot	36	3.42	4

Figure 4.12 Test users pay attention to sound in games more than average.

4.3.2 Test questions

In order to know how people would feel about the sounds during the experience, I structured a set of questions that were asked before, in between, and after playing the environment. The order of the designs to play was varied; every other tester played the two designs in the opposite order. Test user 1 played Sound Design 1 then Sound Design 2, and test user 2 played Sound Design 2 and Sound Design 1, and so forth. Therefore, according to this AB- and BA-test I was be able to get two groups of test users, which can be compared. This way I will also know whether the playing order had any influence on hearing the sounds for the first time and the second time.

I had prepared questions for the user test in the Webropol questionnaire software online. The questions were divided into four steps/pages. The first page was the basic information of the user, such as gender, age, and background. This page was answered first, and then the first environment was played. The second page included questions about the first gaming experience, and the third page had the same questions for the second gaming experience. After the second page questions, the second environment was played. Finally, the third and the last page of questions were answered. On the last page, the questions were related to the comparison of these two gaming experiences and the overall experience of the entire test.

Figure 4.13 Test users answered the questions before, between, and after the playing.

The questions for the playing experiences were the same for both environments because of the AB-listening test method. The questions were about whether any of the sounds felt repetitive or irritating and if the test user would be able identify these sounds. There were also some adjectives, which the user would pick to describe the playing experience. Questions, such as how much the sound fitted the environment, how much the user liked the sounds, and if there were any other characters of the sound that the test user noticed during the experience, were also included.The comparing questions in the end were about whether the test user noticed any differences in the two environments and what these differences would be. The comparison also included questions, such as how did the sound affect their experience and interaction, and finally which one of the environments they preferred.

Because of the different backgrounds, nationalities, and ages of the test users, some guidance was needed with the English questionnaire. However, the difficulties were mostly beyond language, because the ability to describe the sound was much harder for the users. The abilities of the test users to describe or write about what they had heard were also relatively dependent on the length of the test. The fastest users cleared the test in 15-20 minutes, and the longest testings were around one hour. Even though some of the test users asked questions about the sound during the test, I was not able to provide information in order not to influence the test results.

4.3.3 Test progress and monitoring

The playing of the game environment happened twice. I was next to the test users the entire time of test, and before the playing, I gave instructions to follow the light ball, pixie, and to go forward. I also gave instructions on how to play with the controller. Only the two joysticks of the controller were in use; the one on the left was for moving forward, backward and to both sides, and the joystick on the right was for camera view, moving the view of the player. For most of the players the camera view was the most difficult one, they basically forgot to turn their head while playing and tried to move forward to wherever the view was at the time. No other buttons were needed, there was no jump action.

Every other player played the game in the opposite order. The actual first game play time was longer for all of the test users. The first game play was also the one where the majority of the players got lost. The second time became very short, because the majority of the players remembered where to go and what the route was. The first playtime took about five to ten minutes for the test users to play, and the second time less than five minutes. There were also a few test users, who could not remember the route during the second time and got lost for the second time.
All the players, except one, needed guidance after entering the door in the environment, when the pixie disappeared; the visual clues where to go were not there. The sound of the bells was meant to lure the player towards them along the quite obvious route. Instead, people were trying to find where the pixie had disappeared, even though the route was clearly showing to go forward. Some players said they did not follow the route, because they were only looking for the pixie, as was instructed. I had to give more instructions for them to go towards the bells and follow the route forward. Sometimes more guiding was needed, especially if the navigation was too difficult for the player.

Figure 4.14 The Xbox One controller was controlled with joysticks only, the integration with Unity was easy with Xone Controller.

Figure 4.15 Test users playing the 3D environment in a studio space.

4.3.4 Challenges of the user test

The biggest challenges in the environment were in the navigation. People got easily lost at the swamp and were quite disoriented. The guiding of the players inside the game play was half-baked, and the players were not able to follow the intended route. Before starting the test, I instructed the test users to follow the pixie, and they did it very literally. Because of it, most of them missed some of the actions in the game. Also, after the pixie had hit the cloth and disappeared, the test users did not know where to go. This happened to almost every test user, with only one exception. I had to always intervene and guide the users. Therefore the game flow was not successful.

Some of the players got lost on purpose; they wanted to explore the space. Sometimes I had to ask whether the test user was lost or not. Also, exploring as well as getting lost affected the soundscape, as the player did not trigger all the triggers placed along the route. Because of the false navigation that got people disoriented from the route, most of the triggers, such as the "rain on", for the sounds were missed. In order to prevent people from getting lost in the environment, either the route could have been created with the route area being completely restricted so that the player would not have any possibilities to wander around, or the pixie could have shown up again to fetch and lure the player back to the route.

Most of the test users had never used a controller or only few had played with it couple of times. Also, only a couple of the test users owned a game console. Even the gamers had played only with the mouse and keyboard. This was a huge surprise to me, as my thoughts were that with the controller the game would be easier to play. It was quite the opposite; the game navigation with the controller was harder for people than I had imagined. This was also one of the reasons people got lost in the environment, as the navigation with the controller was an unfamiliar way to move in the game.

There were a couple of bugs in the game, and some of the test user made comments about the design mistakes in the game flow. One bug was on the stairs leading to the hill where the game ends. There was something blogging and preventing normal walking on the stairs at one point. This also happened in some other places, when the test user went another way than the route. Because of no jump feature, it was hard to move forward in these places, and it became frustrating and time consuming for the test users to round about in order to get to where they wanted to go.

4.3.5 Discussion with the test users

After the testing I opened up a conversation with the test users by asking them about their experiences and what they had heard during the test. Most of the people enjoyed the test and made it clear that it was very interesting and exciting. I felt that by talking they were more able to express how they felt during the game experiences, and after I told them the differences of the two environments, they were able to recognise or understand the features of the sounds they had heard. I also noticed that some of the test users were unhappy about the fact that they did not notice any difference or if they had preferred the non-generative version. Also, quite many of the test users were hesitating a lot with their answers and sometimes were too shy to write what they had heard, or they felt that what they heard was not actually true or that maybe their mind was playing a trick on them.

Because of the navigational problems, the test users said they were not able to listen to the sounds as much as they would have wanted. Also, during the first playing experience most of the test users said they were so exited and had expectations of the game, which were thrilling, and the adrenaline made them dizzy. Therefore they felt the first experience had too much “going on”, and they did not notice enough elements while playing. Some players were a bit stressed and worried whether they would be able to play the game, some were even afraid what would happen. They said it affected their way of observing during the first playing.

The suspension was there, as I had not given them any clues about the game and the environment, only instructions what to do and how to navigate. Also, I did not say anything about the content of the questions before the test, and some users said they had wished they knew what would be asked in order to pay more attention to the sounds. I had to explain that it was not my intention for them to pay too much attention on the sounds. I only informed them that this is a study about the sound.

Some of the questions revealed to be misunderstood only after talking, even though I had informed all the test users to ask, if there were any questions, or they did not understand the questions. The test users said they mainly had problems in describing the sounds, as they had issues in connecting what sound was which object and what they sounded like. After I revealed the differences of the environments, most of the test users understood what they were hearing and were able to connect their feelings to the sound events. Most of their reactions to the sounds were obvious to me, and I explained why they felt how they did during the playing. I also made it clear that there were no wrong or right answers to the test or how they felt during the test.

4.3.6 Results

The results of the testing had to be divided into two groups: group one with 18 people, who played the non-generative sound design 1 (SD1) first and the other design second; and group two with 18 people, who played the generative sound design (SD2) first and the other second. By comparing these two groups, it can be seen whether the playing order affected the hearing of the sounds.

The first question was how many sounds the test users felt were repetitive, as in noticing that the same sound plays over and over again. When comparing the test users playing the environments and the amounts of sounds they heard as repetitive during both times, there are similarities in the amount between the first play times and the second play times. It seems quite obvious that the sounds felt more repetitive during the second time, as the users had heard the sound already during the first playing. The sound felt more repetitive during the second playing, even if the sound would not really be repeating. The differences are quite minimal, which is why it is quite hard to draw further conclusions. It seems that when the generative SD2 was played first, the non-generative SD1 was felt more repetitive. When played the other way around, no significant difference occurred. However, the slight change in the values between the first and second playing indicates that after the sound has become familiar, during the second time it automatically feels repetitive (see figures 4.16 and 4.17 for comparison). Therefore the order of the playing affected the result enormously.

REPETITIVE SOUNDS

Group 1:

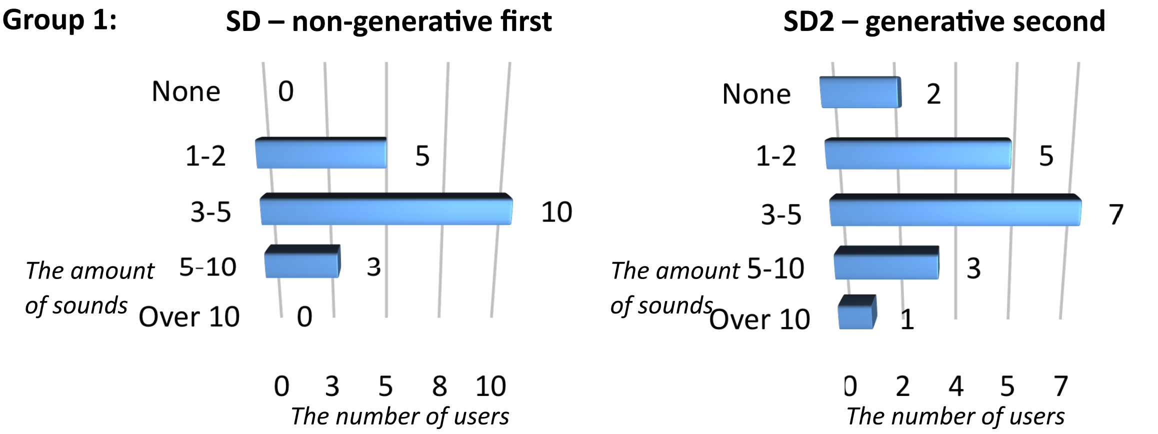

Figure 4.16 The amount of repetitive sounds heard by test users playing the non-generative (SD1) first.

Group 2:

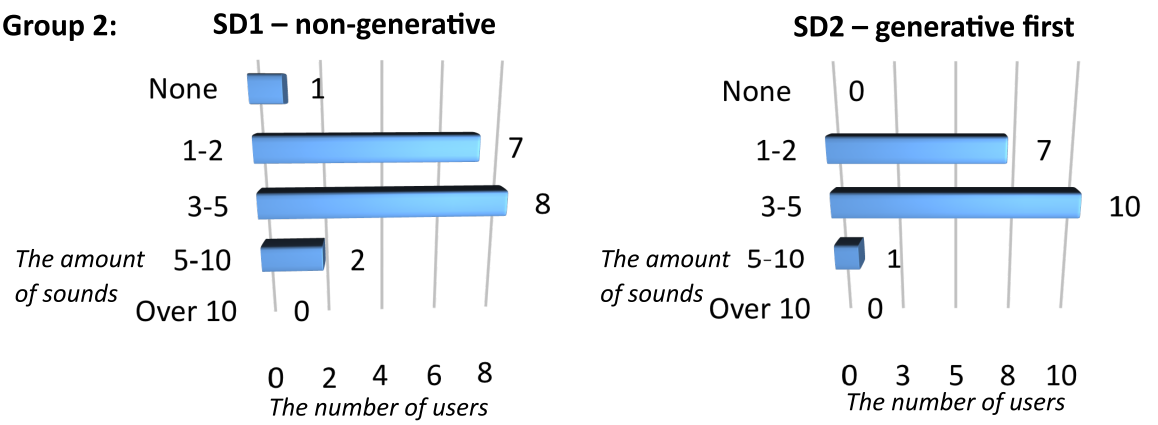

Figure 4.17 The amount of repetitive sounds heard by test users playing the generative (SD2) first.

The repetitive sounds mentioned were mostly the same sounds in both environments, and each sound was mentioned almost as many times in both environments. The sounds mentioned as the most repetitive were the light (pixie), footsteps, wind, rain, and bells. Also sounds such as thunder, water, and the creaking of the pier were mentioned as repetitive.

Besides these, two sounds in the non-generative SD1 design were mentioned as repetitive: the lantern and the birds.

> *"The sound of light sphere was repetitive." (#9)*
> *"Walking (repetitive, especially on the wooden plank it was irritating)." (#8)*

The second question was how many of the sounds in the environments were irritating. The amount of sounds felt as irritative in the non-generative SD1 was a little higher than in the generative SD2. When the non-generative SD1 was played first, the sounds were almost as irritating during the second playing time with generative SD2. When played the other way around, the non-generative SD1 was more irritating. Overall, no significant amounts of differences can be seen and also the order of the playing affected in the same ways as with the sounds felt as repetitive. It could be said that the SD2 included less irritating sounds than SD1 (see figures 4.18 and 4.19 for comparison).

IRRITATING SOUNDS

Group 1:

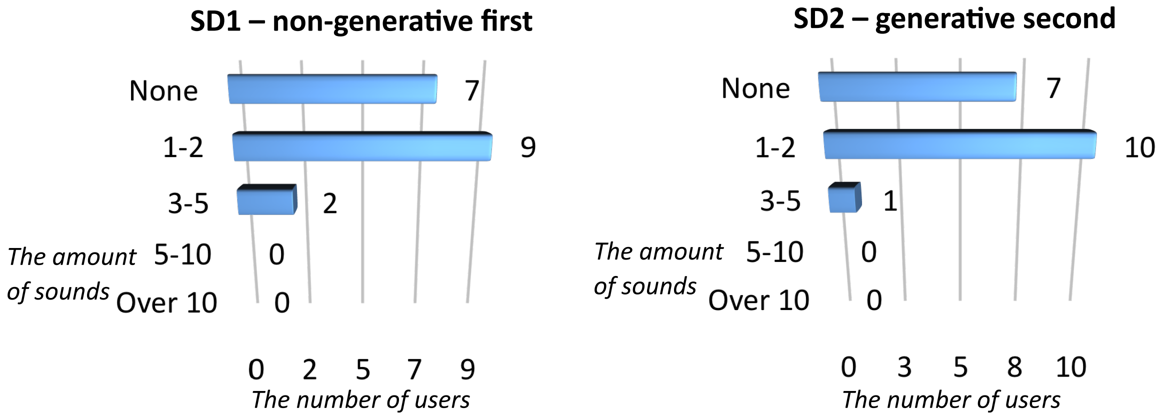

Figure 4.18 The amount of irritating sounds heard by test users playing the non-generative (SD1) first.

Group 2:

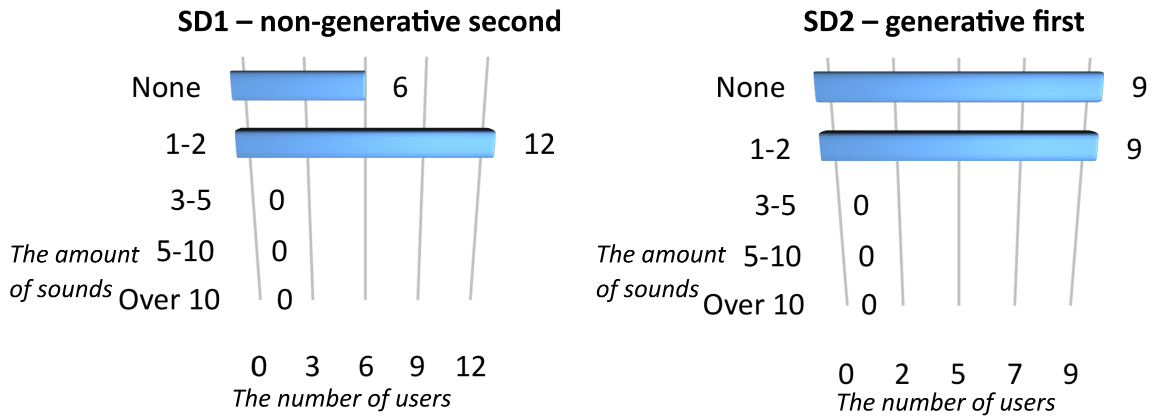

Figure 4.19 The amount of irritating sounds heard by test users playing the generative (SD2) first.

The most annoying sound was by far the sound of the light, the pixie. It was mentioned by 15 people after playing the non-generative SD1, and the number dropped to 10 people mentioning it after playing the generative SD2. The second most irritating sound was the footsteps, which was mentioned by 5 people after playing SD1, and dropped to three people after playing SD2. Other sounds, such as the wind, thunder, water, and bells were mentioned after both play times. Some irritating sounds such as the ending sound, the lantern, and the door were mentioned only after SD1. Also the rain sound was mentioned, but only after playing SD2.

"The sound of the light sphere was irritating, otherwise the sounds of the environment were quite natural." (#4)
"The thunder, irritating in a way it was good stimulation." (#10)

When the test users were asked how well the sounds were fitting the environments, the median of all answers was around 4 with the scale of 0 to 5, where 0 equalled not at all and 5 excellently. However, according to the values given to the non-generative design SD1, when played as the first time, the average was 3.89, and when played as the second time, the average was 4.06. When the generative sound design SD2 was played as the first time, the fitting average was 4.11, and as the second time, 3.94. Thus the total average of SD1 is 3.98, and the total average of SD2 is 4.03. Therefore the generative sound design SD2 was rated to fit the environment better than the non-generative sound design SD1. (See figure 4.20 and 4.21 for comparison).

SD1	**Not at all 0**	**1**	**2**	**3**	**4**	**5 Excellently**	**Total**	**Average**	**Median**
First	0	0	2	1	12	3	18	3.89	4
Second	0	0	0	4	9	5	18	4.06	4
Total	**0**	**0**	**2**	**5**	**21**	**8**	**36**	**3.89**	**4**

Figure 4.20 The values of how well the test users felt the sounds were fitting the non-generative SD1 environment.

SD2	**Not at all 0**	**1**	**2**	**3**	**4**	**5 Excellently**	**Total**	**Average**	**Median**
First	0	0	0	3	10	5	18	4.11	4
Second	0	1	1	2	8	6	18	3.94	4
Total	**0**	**1**	**1**	**5**	**18**	**11**	**36**	**4.03**	**4**

Figure 4.21 The values of how well the test users felt the sounds were fitting the generative SD2 environment.

Also the values of how much the test users liked the sounds followed the same line, although the median in SD1 was 7 and 8 in SD2, on the scale of 0 to 10, where 0 equalled not at all and 10 a lot. The average for SD1 when played as the first time was 7.28, and as the second time, 7.78. For the SD2, the average after played as the first time was 7.83, and as the second time, 7.61. The total average for SD1 is 7.53 and 7.72 for SD2. The sounds heard in the generative sound design SD2 were liked slightly more than the sounds in the non-generative design SD1 (see figure 4.22 and 4.23 for comparison).

SD1	**0 Not at all**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10 A lot**	**Total**	**Average**	**Median**
First	0	0	0	1	2	0	0	7	2	5	1	18	7.28	7
Second	0	0	0	0	0	1	2	5	3	6	1	18	7.78	8
Total	**0**	**0**	**0**	**1**	**2**	**1**	**2**	**12**	**15**	**11**	**2**	**36**	**7.53**	**8**

Figure 4.22 The values of how much the test users liked the sounds after playing the non-generative SD1.

SD2	0 Not at all	1	2	3	4	5	6	7	8	9	10 A lot	Total	Average	Median
First	0	0	0	0	0	1	1	3	9	3	1	18	7.83	8
Second	0	0	1	0	1	1	3	0	4	4	4	18	7.61	8
Total	**0**	**0**	**1**	**0**	**1**	**2**	**4**	**3**	**13**	**7**	**5**	**36**	**7.72**	**8**

Figure 4.23 The values of how much the test users liked the sounds after playing the generative SD2.

There were adjectives given to the test users that they could combine to the playing experiences. These adjectives have been used previously as a standard evaluation process in sound tests by the SOPI (Sound and Physical Interaction) research group at Aalto University in the Department of Media, e.g. SoundFLEX: Designing Audio to Guide Interactions with Shape-Retaining Deformable Interfaces (Tahiroğlu et al., 2014), and also in the study An interaction vocabulary. Describing the *how* of interaction (Diefenbach et al., 2013). In ascending order, the five most chosen adjectives in both environments were: interactive, enjoyable, active, engaging, and intimidating (see figure 4.24).

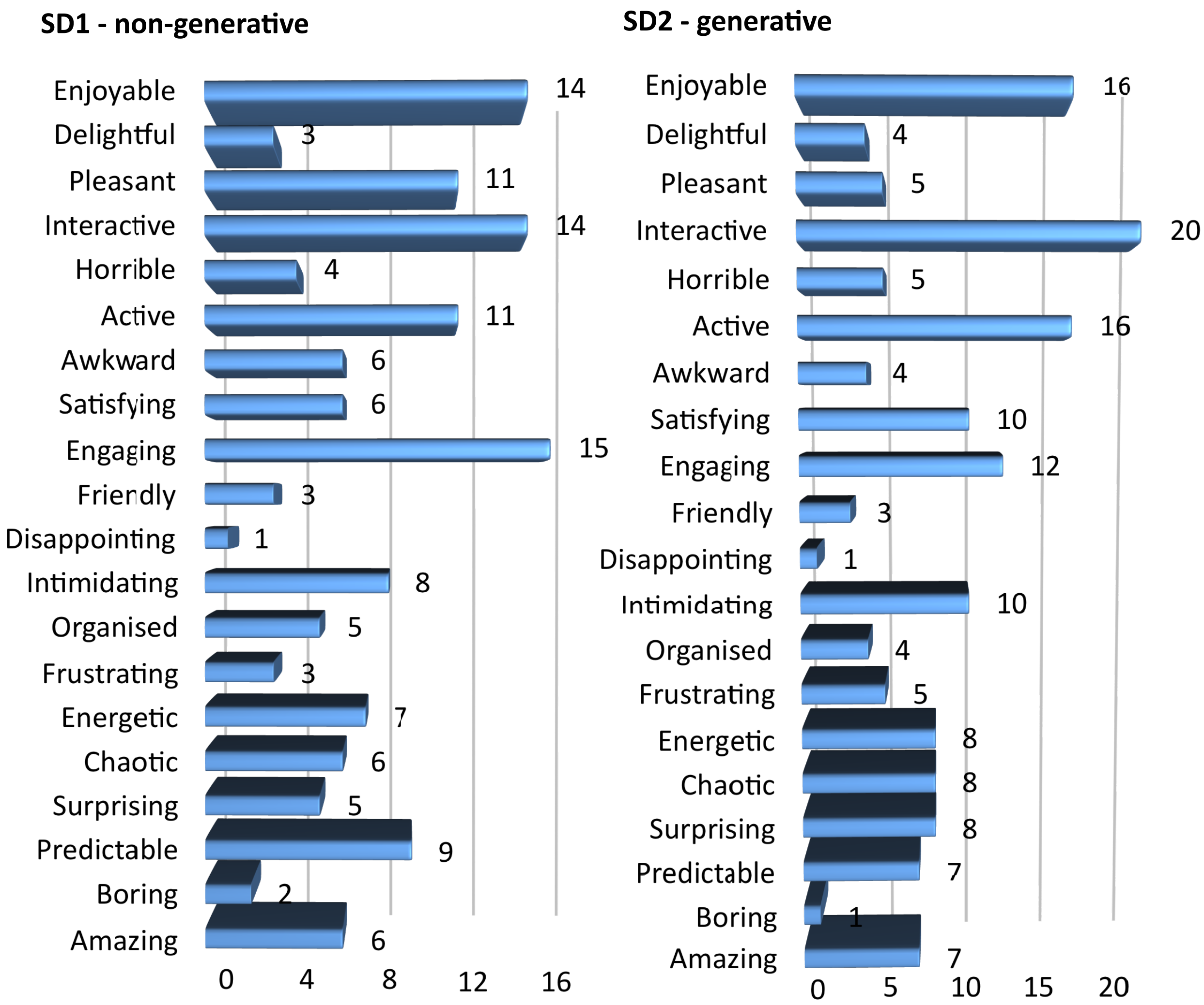

Figure 4.24 The test users selected from the following adjectives to describe their experience after playing.

The non-generative design SD1 was experienced as more pleasant, engaging, and predictable. Instead the generative design SD2 was more interactive, enjoyable, active, satisfying, and intimidating. The biggest changes in the adjectives interactive, pleasant, and satisfying can be seen as the difference between the designs. Interactive was chosen by 20 people in SD2 and by 14 people in SD1. In SD1 eleven people had chosen pleasant, when in SD2 only five people had chosen it. The word satisfying had been chosen in SD2 by ten people and in SD1 only by six people. The word horrible turned out to be misunderstood among the test users; what they meant was a horror feeling rather than the game being horrible. This came up with many after the test during the discussion with the test users.

Overall, the adjectives were quite similarly chosen after both experiences, which proved the gaming to be positively experienced in total, as only a few had chosen the adjectives such as boring and disappointing. The differences between the generative SD2 and the non-generative SD1 were mainly focused on the interactivity, as the SD2 was overall felt to be more active and enjoyable to the test users. The adjectives with the selected amounts can be seen in figure 4.24.

When asked what the differences of the environments were, the differences in the sound designs were mainly presented in favour of the generative sound design SD2. The sounds in the generative sound design were felt to be louder, more powerful, larger, more intimidating, more dangerous, more diverse, and richer. They were said by many to fit the environment better, due to being more realistic and more in balance.

"The sounds in the second environment were much more powerful." (#9)

"Second was more dynamic and engaging. Also it took some of the concentration from movement." (#11)

In contrast, the sounds in the non-generative design SD1 were said to be Lo-fi, deep, repetitive, chaotic, busy, realistic, and pleasant.

"I think it was bit LoFi." (#2)

"I think it felt less chaotic overall, but more repetitive!" (#3)

More nature sounds, such as the bird sounds, were heard in the SD1, but people were more irritated by the light sphere, pixie, sound which was felt as irritating and louder in this design.

"I found it irritating to follow the light ball, because of the loudness of the light ball was too much." (#23)

Some said that SD1 was bland but pleasant, while SD2 was more dramatic and intimidating.

"Version 1 sounded more chaotic and busier." (#14)

"First one was friendly and pleasant, nice sunny day. Second was exciting and intimidating, but I liked it more, it was more interesting with the thunder and the danger in the air." (#35)

Three people said they did not notice any differences between the two environments, SD1 and SD2.

"they were same" (#6)

Overall, the generative SD2 was more appraised and mentioned more positively.

When asked about how they felt the sounds affected their interaction, the test users said that the sounds affected their interaction through many ways.

"Made me look around and look some new things and notice details." (#10)

"I think the light object sound was a clear indicator for me about where to go. That was maybe the most affecting sound in the experience. There wasn't that much other interaction in the game besides exploring, which felt quite natural (sounds supported the environment)." (#13)

"I think it had a large impact on the feel of the experience" (#22)

Four people said it guided and helped them through the environment, and two said the sound did not guide or give clues to them.

"they set the right kind of a mood for a suspense, and they were helpful to guide me through" (#3)

"Sound gave waypoints across the environment. Sounds guided where to look at." (#4)

Five people said the sounds made them feel like they were in the game; they could feel the environment and sounds making it come alive. Basically they felt it was immersive.

"the better sound environment of the second round made the feeling of "being there" much more intense" (#8)

"environment2 I was more drawn into the game" (#21)

Three people said that the game felt really realistic, and one commented that it felt real, even though he knew the environment was not realistic.

"The sounds give me the feeling to being in the place and walking in the place in real." (#7)

"The game world felt very realistic, even if the film itself wasn't realistic. sounds was big part of the world." (#26)

Four people became more interested in the environment because of the sounds; the sounds raised their curiosity.

"the sound raised my curiosity, made me identify with the game world, both times; while first time i felt more intimidated and shy against this new world, the second time i became more confident and actually felt like exploring even more" (#17)

Three people thought the environment was threatening, intimidating, or spooky. This made them go faster in the game.

"They made the game interesting because there was a little danger in the air Intimidating in a good way, thunder and rain made me go faster." (#35)

One felt the sounds were out of sync, one felt the sounds did not come from the right direction, and one said the lack of interaction was quite natural.

"The sound affected my experience a lot. However interactions were affected not so much by sound as poor ability to manoeuvre and constant obstacles on the ground. …orientation was needed for finding right paths etc." (#31)

Overall, the interactivity was felt the strongest with the sounds. Sounds were felt as helping with the interaction and made the game play more active.

When asked which one of the environments the users preferred, the first or the second time, the generative sound design SD2 was chosen as the more preferred sound design by 23 people, 63.88%. SD1 was preferred by 10 people, 27.77%, and 3 people did not know, 8.33%. See figure 4.25. The test users did not know anything about the environments' sound differences or the generativity while answering the questions nor the order of them. Test users had many reasons to pick their favourite, sometimes it was the thrilling first time, and sometimes the second time, as they knew what to do, but mainly it was because of the sounds being better in the other one.

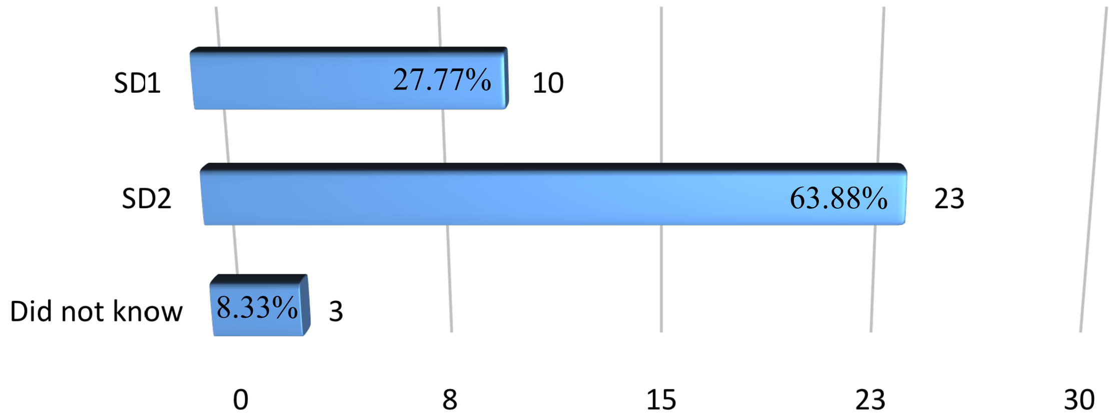

Figure 4.25 The test users preferred the generative sound design SD2.

When asked about the overall experience of the test, it was mainly interesting according to the test users; the word interesting was mentioned by ten people. The word exciting was mentioned by four people in reference to the test or the experience. Five people said the test was nice, three people said it was a good experience and another five people said it was a great experience. Two people said it was pleasant and lots of fun to play the game. Three people mentioned about the bugs and technical issues in the game and two people would have wanted to play the game for a longer time.

"Interesting, could have played longer." (#22)

"The experience was really interesting. Overall it feels great to realize how much sound can affect the experience. The test was pretty straightforward(in a good sense), so it was easy to concentrate on the main issues." (#28)

"A whole new experience, nice. Though, the playing part might have been little longer. It is surprisingly hard to think and put words to the sounds around you, how you perceive them and react to them." (#34)

"It was interesting and made me first time to pay more attention to the sounds. I liked it and playing was fun." (#35)

Overall, the test was experienced positively and the users had fun during the test.

According to the results, it is easy to draw the conclusion that the differences between generative and non-generative sound design can be noticed easily already during a short gaming experience. However, the differences in graphs of the repeating sounds, irritating sounds, and the adjectives are not huge. Instead the result of the preferred environment and the comments about the differences were remarkable. The order of the playing did not have much of an effect on the tests users' ability to evaluate the differences the sound designs. However, the order of the playing affected the ability to notice the repetitive and irritating sounds. The test users' uncertainty during the test was mainly because they were not sure whether to trust their ears and intuition. Audio is completely different from other media formats and therefore the evaluating and judging process of what is heard is complex. This is because the sound has a direct impact on the emotions.

In conclusion, the generative sound design can be noticed, it was felt to effect the experience, feeling, and interactivity more hugely. The generative sound design can also prevent annoyance in the players; it can now be said that it creates a more enjoyable experience. It also results in a more natural and real sounding environment, and enhances the experience and immersion.

To me the results were baffling. I was amazed how much people paid attention to the sounds while playing; they were noticing a lot of details. I was also astonished that they used the vocabulary that I have been using in this thesis to evaluate sounds. I felt the results are quite accurate, and I believe that the ability to detect and perceive sound by the listeners and players should never be underestimated. Most test users had no relevant experience in sound and games, which is why I am very exited about these results.

4.4 Conclusions

The juxtaposition of the generative and non-generative sound designs created a need in me to certify that it is possible to differentiate the perceptions of them by comparing the experiences of them. And indeed, from the results of the research test, it became evident that the generative sound design has more power over the experience. Even if the differences in the individual sounds were not hugely noticeable, the emotional impact was the determinant factor. I personally underestimated the ability of the people to hear the differences, luckily I was wrong. Despite the disturbing other factors, such as the technological problems and the navigational difficulties, the experience of the generative sound design was experienced as more enjoyable, the sounds supported the environment better and gave the users the feeling of a more natural experience.

The route for the environment was relatively short. My assumptions were that the experience is too short to find out annoying repetitiveness, and with a short attention span people cannot make enough conclusions about the sound design they hear. I was also wrong, as the people heard the differences almost instantly. Obviously, in a longer experience, the test users would have become considerably annoyed with the non-generative sound design, even to the extent that they might have refused to play after a while. The test users liked the sounds and playing on the generative design; they wanted to play longer.

The short game made me think, as none of the test users stopped to listen to the sounds and they were all moving for the entire gaming time, whether the sound of the sound objects was changing enough during their short attention spans. The sounds of the moving cloths were not mentioned or noticed by any of the users. Maybe the ability to connect the sounds to the sources was lacking. Some did not even realise the sound of the pixie. Maybe in the end, it is not about recognising the rationalisation and the technology or even about the pinpointing of sources, it is simply about the feeling and being immersed.

The sound of the pixie, the light sphere, became the most crucial sound. It was clear that the sound with the most intention will easily become annoying. It was the one sound that had the most pressure to prove itself, it had a function to guide the user and to make the environment magical. It was also the only synthesised sound, it was a moving sound, and its behaviour was not regular. It was the most particular and exceptional element in the game with a multitasking sound. It was the hardest to design, and people gave mainly critique about it. I think one of the reasons for the critique was the lack of an organic touch in the sound. In the generative design I had added a layer of recorded sound of a porcelain wind bell at the end scene with the pixie, and I got comments that the sound there was not as annoying as everywhere else. It made it quite clear for me how important the organic sound as a feeling to the listeners is, even if it is not something recognisable. A couple of organic sounds, such as the birds, were pointed out, and the users said they felt instantly more relaxed because of hearing them. Although I did not get the chance to try out the procedural sounds because of the missing plug-in files, it made me realise how far the procedural plug-ins really are from the development of game audio. I would have made the winds procedurally. Nevertheless, I actually think it would not have made that much of a difference to the result.

The volume levels had a huge impact, more than I expected, and clearly it was not my intention. I had all the levels in both designs almost the same. It became an illusion where the test users heard some sounds louder than other sounds because of their attentional behaviour. When the sound was irritating, it was felt to be louder; this was very explicit. This proved once again that louder is not always better. Also the technical issues were mentioned several times, and they became problematic at some point. I felt they hurt the flow and therefore the quality of the experience. It was something I was even ashamed of, as I had no testing of the environment done by anyone else than myself. I had to overcome these bugs and ask the users to brush them off as unintentional mistakes in the game play. This made me realise that maybe the user tests in game research should have a trial run only to search for bugs with few test users before making the actual user test. This could actually become a policy to achieve the best test result liability.

I also noticed that the age of the test users mattered. Two out of the three people who did not notice the differences in the environments were the youngest test users. The playing order, the instructions given, and the shyness or tenseness of the users also affected the results to some extent. It was also too easy to get lost in the environment, which created unnecessary frustration and unclearness in the test users. Also the misunderstanding of the questions made some margins of errors in the results. Nevertheless, the test was a success and it was a good feeling to notice how eager and interested the people were to participate.

4.5 Future research

It would be interesting to continue to do this research with all the technical problems fixed within the environment and with a better guided environment. Maybe headphones could be used instead of speakers, and the test user could adjust the overall volume level as preferred. It would be interesting to find out whether the test users would notice the sounds better when using headphones. Instead of the game controller, the navigation could be done with a mouse and keyboard in order to diminish the navigational problems. As these issues affecting the experience were mainly technical and probably easy to repair, the test could be done to larger group of people after the issues are fixed. It would also be a good idea to include more children to do the test. The results of this kind of research could then be compared to the results in chapter 4.3.6 in order to see whether they match or differ, and the reasons for the similarities/differences could then be researched.

Future generative sound research could also include the quality and generative features separated into two different tests. Also tests between a game created with procedural sounds and a game with recorded sounds only could bring more information about the perceiving experience. Some different kinds of generative sound design tests without visuals and with or without interactivity would also be intriguing. I wonder whether the results of these sound design tests would resemble the results of a design with visuals in any way.

5. Case Study 2: A generative sound installation

I became fascinated by sound installations, and while working with programmable sounds, I decided to build one. I wanted to create new sonic experiences whether they would be interactive or not. Throughout my master's studies I have been building and programming setups where manipulation of the sounds happen either randomly and is controlled in the programmed software as a standalone or by the user. The users' or listeners' experience of this sonic discovery has been surprisingly positive and ground-breaking as opposed to people thinking extra sound is always either noise or unwanted. I noticed that with sound installations I am able to transfer people into different spaces and dimensions along with an emotional impact. However, I felt that the installations I had seen were lacking in narrative. I found it disturbing, because I think the design process with sound installations should always be story- or feeling-driven, especially when being designed to a certain space.

I was on a SuperCollider sound programming lecture, when I got an idea to manipulate sample sounds that would play in a loop simultaneously and create the sound outcome a little differently all the time. The idea developed further due to the request for sound installations by The Nordic World Mandate seminar organisers. They wanted a sound installation to the lobby of the space for their event. Then the creation of FFF-Finnish Forest Frequencies sound installation began.

5.1 Finnish Forest Frequencies sound installation

Finnish Forest Frequencies (FFF) is a sound installation that I originally designed for a specific event, The Nordic Mandate, to the lobby of Aalto Arts University in Hämeentie 135 C. The event coordinators were hoping for sound installations presenting Nordic and nature elements. The FFF-installation started with the idea of bringing the outside space inside, a forest to the lobby area.

Figure 5.1 The FFF sound installation at the Aalto University lobby and attached to the glass windows.

After planning which area from the lobby I should take, I noticed the huge glass wall. Earlier I had seen some new speaker technology by Feonic that would be great to test on the glass window surfaces. The devices were small sound actuators that turn the surface where they are attached into a speaker. I chose this new technology to be my main output for the sound. It was interesting and would utilise the acoustics on the space. With this technology I would be able to turn the glass wall into a forest.

The installation would need to be multichannel in order to create the sound space, as there were five separate glass windows. I was not sure whether these windows would resonate, but I was eager to find out with some testing. I was also sure that the space and the corridor would also emphasise and affect the sound acoustically.

5.1.1 Narrative and meaning behind the sound

After being asked to create something from the themes of being Nordic, Finnish, and nature I immediately thought of forests, as the Finnish identity is the forest. People go to the forest to listen to sounds and to relax, to get strength, and to be inspired. The problem is that forests are so far away from the city that people do not have time to go there or maybe not even possibilities to find a forest that is free to go to. I thought that I will bring the forest to the people in the city, to a space inside. Then people would have the chance to listen to the forest and imagine they are surrounded by the atmosphere of the forest.

Then the idea of the forest being heard in an inside space became wrapped around the thought of what we hear in the forest, what really are the frequencies being heard there, and which of them are the most heard and dominating. It was the beginning of the summer time, and I immediately thought of the winds, the birds, and the movement of the trees. Basically I needed to find out how a Finnish forest sounds like without any traffic and human made sounds.

I felt the sounds had an importance because the frequencies and sounds of a natural forest are quite rare nowadays; basically it is turning into a dying soundscape. The sounds in the forest have always been a relaxing and stress relieving experience to the people, especially to the Finnish people who go to the forest to calm themselves and to be quiet.

5.1.2 Recreating space with sounds

Figure 5.2 The recording gear with me in the forest.

I decided to go and record a forest by myself somewhere where I could not hear any man made sounds, noise or other sonic distractions. The fact that I could not travel too far was limiting my recording session and I gathered the recording gear available. On my trip to my home town Tampere, Finland, I finally found a forest nearby, in Vesilahti, which I figured would be quiet enough. I only assumed this by looking at the map and pondering on the locations of the forests around the area. After some wandering, luckily a nice man living next to the forest guided me with some instructions on how I could get to the quietest places of the forest. I recorded the forest in about ten minute clips from several places. I could hear the wind, the trees and leaves moving along with the birds singing. One of the trees was creaking in the wind. When the day turned into evening, I could hear some animal movement and sounds in the bushes. Overall the soundscape atmosphere was very pleasant and soothing.

After the recording session I analysed the recordings with a spectrum analyser to see the differences in frequency ranges of the recordings and easily found the most dominating frequencies from them. Instead of hearing the entire frequency range of the recordings, I decided to pick the five most dominating frequencies, play them, and find out whether it would as an abstract and minimal sound representation still sound like the forest.

I was wondering how to recreate this forest to a space, mainly to the five glass windows on the wall. I wanted to separate the dominating frequencies into parts, and by parts I mean different audio channels. Therefore each frequency would have its own output channel and own window. This way I would recreate the space with the frequencies; one frequency would be heard only from one actuator in the installation. When hearing them all playing together, they would form an entirety of the forest as a sound illusion to the space.

5.2 Implementing the sound installation to the first exhibition

In order to learn SuperCollider audio programming, I chose it as the language to implement the sound installation. I realised that when creating something complicated, it would be easiest to build it with the SuperCollider. Even though the idea was simple as well as the outcome, I wanted to create as little programming as possible. Also, I figured that further development of the installation would be simpler to do with this programming language, because the usage of SuperCollider script is very straightforward, fast to implement and execute. The stability of the SuperCollider was also praised as being robust.

I was also fascinated by the aspiring new speaker technology by Feonic Technologies Ltd., the sound actuator. This little vibrating machine would transfer the sound as vibration to the surface where it is attached and make it resonate, turning the surface into a speaker. The best surfaces to use for an actuator like this are glass and metal. I had previously seen a video of an installation in the botanical garden in Helsinki by sound artist Kristian Ekholm. He also studied at the Media Lab during the time and owned some of these actuators. Because our school only had three of them, I asked him if I could borrow a few of them for the exhibition and luckily he agreed.

I ran some tests to see whether the glass windows would resonate because I had heard that not all of the glass surfaces resonate with the actuator, especially if the glass is too thick. I created a small setup with one actuator and tested the resonation. As a result all the five selected frequencies were clearly audible with the glass. After the test I completed my programming, which included five frequency filters, one for each sound file. All the loops were edited to be of different lengths, and while being played together, the change of the cycle would make the sound outcome different and changing in the sound space.

When I attached all the five actuators to the glass windows, I realised at this point that the frequencies did not sound good enough together. The space was not full and rich enough to represent a forest. Previously, I had programmed the system to select a certain frequency of the recording with the help of the filters, but now I set each of them to play a little wider frequency range from the recordings. This made the space more alive and the surfaces started to resonate better. The long and echoic corridor from the glass wall helped the sound to continue and resonate along it. When entering the door through the wall, it felt like entering another sounding space, a forest.

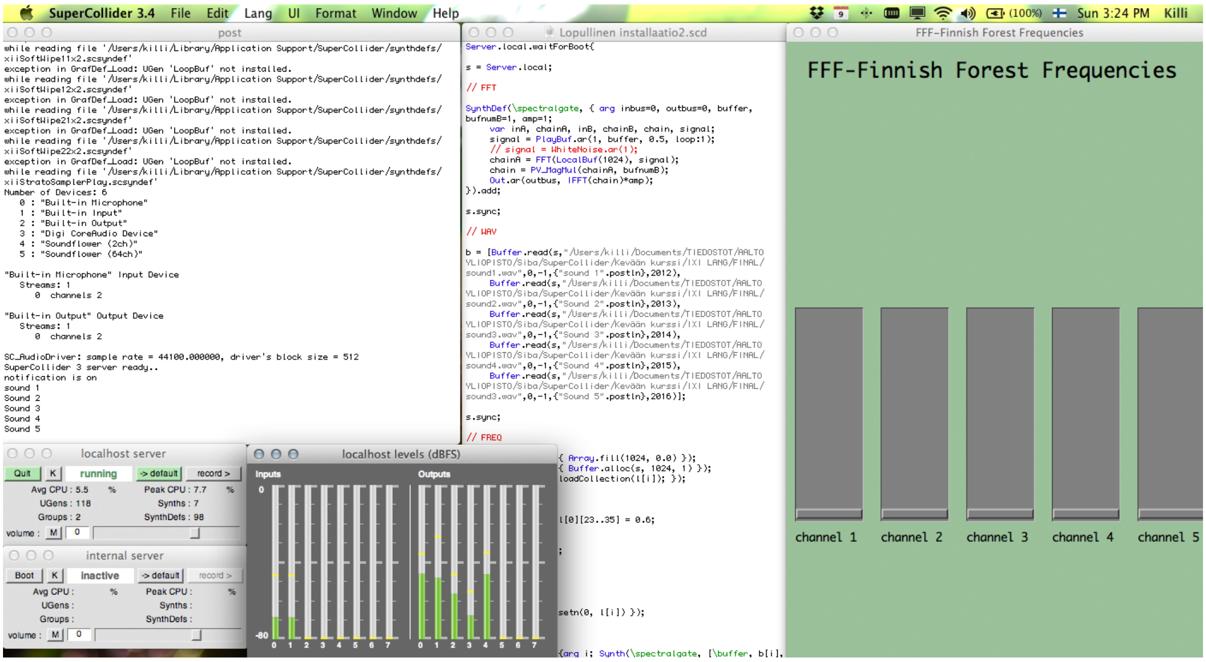

Figure 5.3 The first iteration of the SuperCollider code.

5.2.1 Audience feedback of exhibition I: Feeling the space

To find out what the people visiting the Nordic Mandate would think about the sound installation, I put up a feedback box with a competition. When people would leave a comment about the installation, they would be part of the lottery to win a package of traditional Finnish food items. Unfortunately I only got 8 comments, which were only one or two words, and one phrase long in maximum. The comments included mainly “ok”, “good”, “sounds nice”. Only one of the comments was longer and that person I knew. I felt quite disappointed. It seemed people were more interested in getting the price than actually giving any feedback. This kind of way to get feedback clearly did not work. I figured the feedback of an installation can really be received best when watching people and their reactions among the installation, and by talking to them about their impressions and experience.

Figure 5.4 A photo taken from the centre of the forest became the graphical representation of the sound installation.

While talking to the listeners, I noticed that they immediately realised they were in a forest or entering a forest when walking from the door to the corridor. People definitely noticed the sound space as a transportation to nature. Especially the janitors at the lobby felt irritated by some of the frequencies, when one sound was a bit too short and the same bird singing high frequencies repeated too many times over time. They noticed that the same sound was just being played over and over again. What people did not understand was the fact how it was made or what the story was behind the execution. Many were actually more interested in how the installation was technically made than simply enjoying the experience. It was obvious to me that the sound was lacking either in narrative or the experience somehow.

Some other challenges were also present at the exhibition. Because the computer was hidden behind a small white wooden booth that was not locked, but only turned against the wall to hide the technology, someone occasionally turned the booth and put the amplifier off. This happened several times during the exhibition. I never found out the person or the reason for someone to turn the installation off, instead I figured that either someone from the staff was bothered by the sounds or the night guard did not know it was meant to play all the time and put the power off. I learned that in the future exhibitions, which will last for longer periods of time, all the technology needs to be behind locked doors.

5.2.2 Modified intermediate version

After the first exhibition I forgot all about the installation, as I had figured that the installation was completely site-specific and one time only for the lobby area with the glass wall. Then I met Topi Mäkinen, an architect student, who was looking for a sound designer for his project of a wooden house. Soon I ended up testing how wood would resonate with the actuator. The long, old and dry logs vibrated amazingly well, and as a result, the actuators were placed and hidden inside the logs.

The wooden log house or a Finnish old hay barn was chosen as a finalist in the Habitare Design Competition 2013, and the theme for the competition was “Dream Space”. According to the theme, I came up with a narrative on top of the forest sounds. I created a dream for the log house with sounds from old tools that the builders used to use when creating these old log houses in Finland in the past. I recorded these different tools in a restoration centre in Seurasaari along with some ambiences, creaky doors and floors of some old log houses. I combined these sounds with the forest sound and on top of them a breathing or snoring sound of the log house as surround. I recorded some puffing air of an accordion at the Sibelius Academy. This way the log house would come alive. At this point the installation was given a new name: Ladon Uni / House of Sleep.

The installation extended into eight channels. I also found a bass actuator, which was kindly borrowed by lecturer Marianne Decoster-Taivalkoski from Sibelius Academy department. I placed the bass actuator under the floor of the log house which made it shake. I placed one actuator on each of the four walls and three to the ceiling logs.

This project made me realise that the wood resonates, vibrates, the sound can be touched, and the sound travels from a wood piece to another when they are linked. It gave me more ideas and I met a lot of people who gave me feedback about how excited they got after this listening experience. In the end, we placed second in the competition. Because the log house was too big, heavy and difficult to transfer to another location with the electronics, I wanted to create a lighter and better version of my original idea of the forest sounds, the Finnish Forest Frequencies sound installation.

Figure 5.5 Ladon Uni / House of Sleep at the Habitare 2013 Design Competition.

5.3 Making the installation touchable in the second version for Japan

I started to plan a sound installation for the course "Production Clinic" held by the Media Lab, Aalto University. On the course I began to create a new joint installation together with photography student Johanna Rotko. I was one of the selected artists along with her to the exhibition meant to be created to Spiral Garden in Tokyo, Japan. The installation would have my Finnish Forest Frequencies sounds together with her photographs somehow.

After several brainstorming sessions I decided to create a recreation of a Finnish forest with sounds and pieces of wood, along with a wooden stomp. The installation would be based on my previous installation made with Finnish Forest Frequencies. I wanted to do an 8 channel installation with Feonic sound actuators and place them inside Finnish naturally dried wood (deadwood). Because I did not have enough actuators from school, I contacted Feonic Technologies and they agreed to be my sponsor for the installation.

5.3.1 Building the entire installation from scratch

I began searching for wood and soon I was given pine deadwood from Äänekoski, a place in the middle of Finland. With some help, a long deadwood tree that had died in the forest over a hundred years ago, was taken down and cut to pieces, small round pucks and longer tree trunks. I also wanted to find a big stomp, which was my original idea for the installation. It was meant to be the centre piece of the installation. The stomp was luckily also found from the forest in Äänekoski and given to me by Esko Tourunen. The stomp was also naturally dried, but it was a stomp of a fir tree. Unfortunately later I found out that the stomp was against the regulations of importing raw wood to Japan, and also the transportation would have cost too much. Therefore I planned to save it for later, for an exhibition in Helsinki. I replaced the stomp for Japan with a bigger piece of wood, the stool.

After gathering all the wood and making some tests with the actuators, I found out whether the wood will be resonating enough or not. I hanged the tree from the ceiling but the tree would not resonate enough. The wood was too wet from the forest, so I would need to dry it. The wood was transported to Helsinki, to my school and into the wood studio. Soon I noticed how the sound became better and better once the wood was drier. In order to prevent the wood from cracking too much, I began to dry the wood so that it would dry as slowly as possible in the wood studio. I put a lot of wood-glue from time to time onto the wood pucks and at the end of the trunk pieces. I let the wood to dry as long as I could.

Figure 5.6 Drying the wood with glue.

When the time came that I just had to start handling the wood, I started to sand the glue off from the pucks and began to drill holes inside the wood. It took several tests how to do this because the wood started to crack very easily from where the hole was made. At some point, I had an idea to hang the wood in a way that the metal hanging part would cover the hole and the actuator inside the wood. This led me to work with metal because such metal pieces were not sold anywhere.

Figure 5.7 Inserting the actuators inside the wood.

The metal parts needed to be done individually for each wood piece, because all the wood surfaces curved a little bit differently. First I made metal plates with screw holes and then welded hooks onto them. Also metal wires needed to be done for the hooks. There were several steps to these that needed careful execution because of safety issues when hanging big wood pieces.

After the wood and metal works were done, I started to place the actuators inside the wood and do some sound testing. I needed to measure the audio cables to certain lengths and also solder the audio plugs to them. Before finally placing the actuators inside certain wood pieces, I tested the wood with each frequency and selected the best resonating wood piece for that frequency range. It sounded better and louder, when the wood piece resonated well with the frequency.

Then I started hanging the wood and doing some tests with the sounds levels. The testing turned into programming more with the SuperCollider audio coding language that I had created my installation software with. After playing the sound installation as it was on the trees with only a few frequency ranges, it did not sound interesting enough. The sound design needed altering. This became a crucial point to me, as I personally thought that the installation was becoming generative. I got more and more ideas of how to make the soundscape more interesting. From there on, the forest frequencies have been breathing more with the sound levels, as I made random sound volume level automation onto them. I also added some Finnish animal sounds that randomly play from any of the hanging trees at random times.

Figure 5.8 Testing the sound levels.

After the programming was pretty much done and I was happy with the results, I started to do some packing for the transportation to Japan. I was afraid that the wood would completely crack during transport. This was exactly what happened to one of the puck pieces. I had to change that to a spare one, which I luckily took just in case.

Making the sound installation with a material as an object and especially that material being wood with metal has been one of the most arduous processes I have ever done with sound. Creating the entire sound installation by myself demanded a lot of work and hours.

5.3.2 Challenges at the gallery

In Tokyo at the Spiral Garden the setting up was easy. I only had to show the Japanese builders how the locks and attachments would be used. Everything went according to my plans and calculations with the distances of the wood pieces. I was really happy with the appearance and decided to have a dramatic spot lighting on all of the wood pieces, and double lights for the wood piece on the ground where you could sit and feel the vibrations of the bass actuator. This was the replacement wood piece instead of the stomp.

I was a little worried about the sounds. Next to the area was a café, which seemed to have quite a lot of people and was therefore very noisy. Also the carpet floor of the gallery area seemed to suck most of the sounds, and the high ceiling did not help either, as the reflecting surfaces where all very far away. When I turned on the computers, I immediately noticed that I had to turn the sounds almost to maximum volume levels. I also had to make the sound automation spans smaller and faster to make the changes in the sound design happen faster, as the people did not spend that much time among the installation, and also make the sounds of the animals play more frequently and more simultaneously. As one of the wood pieces broke during the transportation, I had to change it to a spare one, which is why I needed to do a little more adjusting with the sound in order to make it resonate better.

I had the wood pieces attached with transparent fishing lines to the floor to prevent people from making the wood to spin and swing. Unfortunately people did not see them and got tangled to them easily from their bags and clothes. Small children hit or ran into them. Because of this I had to take them off and take the risk of people making the wood spin and swing. Luckily the area was controlled all the time by someone and the visitors were behaving nicely; no dangerous situations occurred.

After all the modifications, I felt quite relieved, and I was proud of myself for getting everything done. It had been a lot of work and I could finally see and hear the result of my work in the space where I had designed it for. Despite all the challenges, the sounds were playing well and the system seemed to work fine, the program was stable and everything worked fine during the entire exhibition.

Figure 5.9 Finnish Forest Frequencies with resonating and hanged deadwood in Spiral Gallery, Tokyo, Japan.

5.3.3 4D experience with the object, smell, vibration and sound

The object, the wood, itself became visually very appealing to the people. The beautiful colour of the deadwood and all the details of the surfaces on it made people interested in the wood. It roused many emotions in the listeners when they touched and hugged the wood. Not only was the sound relaxing, but also with the touching, a relaxing feeling was achieved.

The smell of the wood was very strong and detectable even while not being very close to the wood. I also felt that the smell became even stronger while the wood was vibrating. The vibration definitely had an effect on the wood's behaviour, and through that to the sound. The sounds became louder with time. This was caused by the process of the wood still drying, and the wood also behaved differently in different spaces because of humidity and temperature.

Soon I realised that due to what I had done, the wood had more dimensions than being a touchable and resonating surface. The sound was so powerful in the dry wood pieces that it made them shake and vibrate. It was easy to feel the vibrations when touching the wood. The vibrating wood created an instant experience change; it was the surprise moment for the listener.

The vibration, smell, sound, and the touchable object had turned the installation into a 4D experience. The installation was not only about the sound, it became an experience with a visual appearance together with the sound. The sound obviously became more understandable to the people this way along with the narrative story behind it.

Figure 5.10 People touching and listening to the installation in Spiral Gallery, Tokyo, Japan.

5.3.4 Audience feedback of exhibition II: Relaxation

As soon as the people noticed the wood, they immediately rushed towards them, started to touch them, and turned them around. They also began to sniff the wood and hug them, pressed their ears against them. The reaction and behaviour came naturally and easily. Everyone did it almost the same way and in this order, no matter whether the listener was a child, an adult, a woman, or a man. However, some people were very timid in touching the wood, and I believe this was because the Japanese people are quite polite and shy. But as soon as they saw someone touching the wood or listening to them they followed and did the same.

The most challenging was the stool, the piece of wood where I intended people to sit on. People did not understand that it was allowed and intended to sit on it. Therefore, after the first day, I had to put a sign with English and Japanese texts that it is allowed to sit on the stool. Soon people started to sit onto the stool, and the reactions were thrilling. Especially girls started to giggle, laugh, and even exclaim quite loudly. I noticed people commenting that there was something sexual about the vibrations of the stool. I found it quite funny.

It seemed that people really enjoyed the wood and the sounds; they thought that the experience was fun and relaxing. I even got a letter from a woman who had sat on the stool for long times and came to hear the installation on several days. She explained how it had taken her back to her childhood in the countryside where she used to spend time in the forest. Now while in Tokyo, there are only a few trees, so she misses the forest. The installation roused those memories and helped her to relax while transferring her to the forest from her childhood.

Figure 5.11 People's reactions to the installation in Spiral Gallery, Tokyo, Japan.

5.4 Bigger wood to the third version

After the exhibition in Tokyo I had plans to realise the installation in the intended size which I had designed. I had stored bigger wood pieces and the stomp to wait for implementation. I transferred the equipment into these and started new sound tests.

Because the wood trunk pieces were heavier, I decided to secure them with double locks for security and also made wiring from the bottom of the wood pieces to the floor where they would be bolted. This would secure the wood pieces on their places and prevent people from swinging and spinning them. Under the stomp, I also placed a rest piece which would keep the stomp a little of the ground so that the actuator placed on its end would not hit the floor. All the cables were hidden along the roof lines and taped carefully. On the lower roof area, some holes for the hanging were drilled to the roof panels so that the hanging would look better and hide the cables above the lower roof level. All cables were then led to a locked space, a spare toilet and shower room, which was not in use. I placed all the equipment there, and I had electricity there to power everything.

5.4.1 More rules and sounds

I had to make more adjustments to the sounds, because the space was for relaxing. In order to prevent the sound from becoming too tiring, I added a wider volume level automation. Sometimes the installation would be very quiet and sometimes louder, and everything in the between. The time spans would be longer in order to not have too sudden changes. My aim was to make the forest breathe smoothly.

Because I only had a few animal sounds, I added more sounds to increase the variation and avoid fast repetition. I made the system to play the sounds for longer random times, because people were staying in the space for longer times than just passing through like in the gallery. Sometimes it played for long times without any animal sounds, which was good since you cannot hear wild animals in the nature that frequently either. I wanted the soundscape to be relaxing, more real, and give time to breathe while perceiving the sounds. As the soundscape was calmer and smoother, it made the listening experience for this space more interesting. I wanted to create the feeling of people wanting to listen to it forever, feel like being in a real forest, or just to be curious to find out what animal can be heard next.

Figure 5.12 Finnish Forest Frequencies, the third and full version, in the Kainuu space at Helsinki Airport.

5.4.2 Challenges of the airport

At the Helsinki-Vantaa airport the biggest challenge was the space without any supervising. There were no security cameras and the guards did not visit the place almost at all. I had to prepare the installation to last the misuses of the people. However, at the time I was not sure what the misuses would actually be. The first problems were that the people had been turning the stomp around, and also the cable under the cable chute had been torn. After some time, two of the smaller wood pucks had broken. The lower wire had suspension and had torn the bottom of the buck rip from the wood piece. These particular pieces of wood seemed to be more fragile than others, and I believe they broke only because the wood was drying and cracking, although I cannot be sure.

One of the bigger wood pieces came down completely one day, because someone had obviously been hanging on it, most likely some children. The wood had fallen with such power that all the metal pieces and hooks had completely bent, and the actuator had popped out from under the metal plate. Because the screws were not long enough, the metal plate had detached from the wood. After fixing I replaced the screws with extra long ones so that it would not come down even if children would hang on it.

Sound was hard to mix in the space, as the carpet floor did not make the stomp resonate as well as I intended. However, the glass wall reflections in the room amplified the frequencies. Therefore I had some issues with volume levels; some animal sounds sounded louder than others. A huge problem with the mixing of the volume levels was that I needed time to do it in the space, and I did not have it, because every time I visited the space, I needed a staff member to guard me there, as it was located in the passenger area and naturally I had no passport or plane ticket. Therefore I always needed to hold someone there with me from their normal job duties.

The biggest problem was the electricity. Unfortunately the electricity was attached to the same power area where the airport was renovating a new space for passengers. From time to time, they were cutting off the power, and it also shut down my installation. I had to go to the airport to start the system, as it was not that easy for anyone else to start it, and I was the only one who was able to do it.

5.4.3 Audience feedback of exhibition III: Misbehaviour and volume levels

There was some misuse of the wood pieces by the visitors. One wood piece included written text by someone. I could not understand the language so I was not sure what was written on it. One wood piece came down after someone was hanging on it. The stomp was turned around several times and the support piece had been taken off and screwed to another hanging wood piece. Also some of the bolted wires detached from time to time, because the carpet was so soft that the screws came up. Some small pieces had been taken as a souvenir from the wood tree trunks and the stomp.

Some complaints about the volume levels were given to the airport by some visitors. They felt the sounds were too loud, which is why I was asked to adjust them at one point. Even though the levels were pretty quiet, I sometimes felt that I could not control them properly, as over time the wood structure changed while drying and the levels kept rising. I felt that the complaints sometimes were just people being annoyed by the fact that there are some sounds. This was surprising to me, as the sounds were from nature. However, because the space was mainly used by people to sleep between flights and they were tired, they got annoyed. Therefore I believe it did not matter what the sound was, as it would have annoyed anyway. The space was clearly not only the relaxing space as intended, people used it as a sleeping space, and while not being able to sleep due to the sound, they became annoyed.

However, one family contacted me through email by saying that some of the actuators must be broken, because no sound was heard from a few of the tree trunks. After checking that everything worked I understood that during the time they were listening some of the volume levels were simply down, as the volume levels were automated. It was not intended that sound would come all the time as loudly as possible or as static, or that any of the trees would go silent.

I had a plaque on the wall where I asked people to take pictures and post them with a hashtag #FinnForestFreq to twitter about the installation. Unfortunately only one of the visitors did it, besides a few of my friends. The installation did not gain any social media attention among the visitors, or if it did, I could not find out about it. I was hoping for people to send pictures of themselves listening to the wood, like selfies. Unfortunately that did not happen.

Figure 5.13 People listening and relaxing in the Kainuu space at Helsinki Airport.

5.5 Installing interaction to the sound installation

I wanted to create an interactive version of the sound installation by trying to make the wood pieces interactive to the listeners in the space. Technically this became a challenging task, as making an entire wood piece interactive was very problematic. If the interaction would come with the touch, then either the surface or where the wood is hanging should be the trigger. Installing sensors inside the wood would become very difficult, and I would also need to double the cabling. Therefore, I approached this idea with depth space recognition with Microsoft Kinect camera with which I could make the areas where the trees are hanging sensitive to movement.

With the help of Régis Frias, we were able to attach the movement of the hand in certain areas in the air; when placing your hand to the certain area, a sound of a random animal would play. When placing the wood to that area and then touching the wood in front of the Kinect camera, the animal sound would play.

The software with the Kinect was created with the visual programming language Processing and it was sending the audio information as OSC to PureData. As I was not using PureData but SuperCollider as my audio programming language, I had huge technical problems in integrating. Overall just getting it to be stable without crashing was problematic. I was also not able to get the OSC communication to work without crashing with my software in SuperCollider. The Processing was not stable and the communication with SuperCollider was simply unsuccessful. Already just to get the Processing to work was problematic, because some operating system updates were preventing the Processing from working properly.

One of the most crucial issues with the interaction made with the Kinect camera was that it would detect the hand movement only from one side of the wood piece, as the hanging wood would block the camera's detection in the air from the backside of the wood piece. Interaction would not be possible all around the wood piece, so I had no choice but to reconsider whether the interaction would be worthwhile.

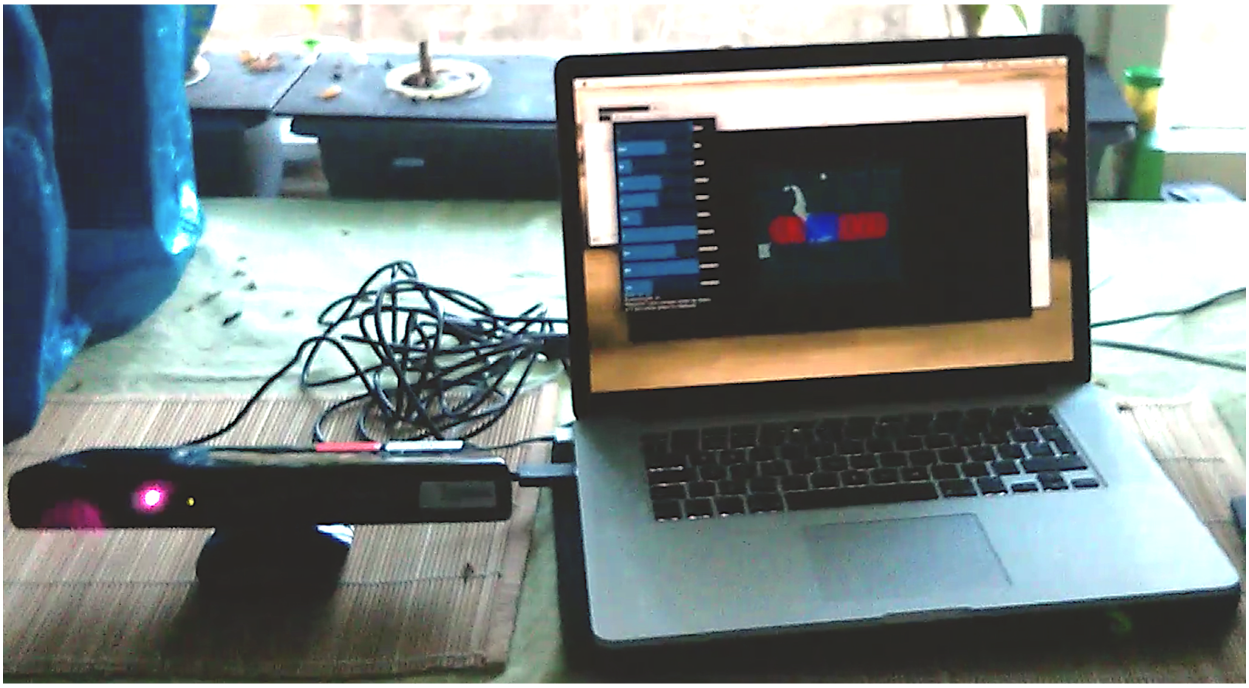

Figure 5.14 Testing the interactive version of the sound installation.

Touching the area (red ball in the software) in the air with your hands triggered the red ball to be blue and play the animal sound (see figure 5.14). These ball areas were possible to place wherever in the Kinect camera view range, which is proximately 2 metres times 2 metres. Therefore this area is quite small. A large installation would need several Kinect cameras and several computers to make it completely interactive. Also the placement of the camera should be quite close to the wood pieces and the placement of the ball areas reprogrammed every time the placement of the wood pieces would be changed.

Obviously the technical problems were huge, and I started to realise that the interaction is not really needed. I began to ponder the following questions: Would interaction actually bring anything more to the experience with the wood? How would the interaction affect the sounds? While the sounds would be affected by the listeners, what would it do to the listening experience?

5.5.1 Engaged experience vs. interaction

Even though I managed to make the installation interactive, I felt the arguments for the interactivity were lacking. I asked myself why interact with the sounds in the forest and why hear a sound when touching the wood. The thought of the interactivity with the wood and the touch was clever and smart, although after implementing it did not feel right as an experience. I noticed it did not fit the concept of the sounds in the forest. To create the wood as interactive because of interactivity is not enough to intrigue the listener, therefore the technology turns into unnecessary trickery. The interaction should be justified in the narrative and not done only as the ambition of discovering whether it can be done.

It is unnatural to touch a piece of wood and immediately hear an animal sound. When walking in the forest and touching a tree, it is not possible in real life to command the animals to make a sound. The interactivity simply does not fit the soundscape content and the entire concept of the installation. Overall, interactivity with immediate response does not fit the installation. After talking to many people about the interactivity, there simply was not enough justification for it. I came to the conclusion that it would not bring anything more to the experience. What would be the real benefit of having the interactivity in the installation?

A sound installation can be “interactive” in an engaged way without affecting the sounds or the soundscape. The smell, the vibration, and the sounds of the wood together with the spatial experience invite people to engage. This engaged experience of the installation already gave a strong sonic experience to the audience. Sometimes people already thought that the installation was interactive somehow. These other multi dimensions and elements of the installation uplifted it already to a high level quality in the experience. The wood itself creates such a strong experience, and together with the sound, it becomes even more engaging. Therefore, if implemented with too many strong elements together, the result in this case would be too overwhelming.

The final outcome is elegant and beautiful. If the installation would be interactive, it might jeopardise the beautiful outcome also in the sound design. However, if interactivity would be included in the work, it should be very subtle and maybe done in another way, for instance according to the amount of people in the space, something in the soundscape would change. For now I believe the installation does not require any interactivity. Interactivity is not always needed to enhance the experience.

5.5.2 Smaller versions of the installation

I also had two smaller gallery exhibitions, one at the AMF-Gallery and one at the Media Lab demo day. I only had three pieces of wood hanging in these exhibitions. My aim was to make these exhibitions interactive, but the technical issues were too challenging in order to implement it. I also felt that the installation was not very interesting sound-wise because of the small spaces with only three wood pieces. It felt like the sound did not fill the space enough. Instead of creating a space of a forest they became individual pieces of resonating wood.

However, these were very good learning experiences and I received a lot of positive feedback. Only one problem occurred: during the AMF-Gallery exhibition, the space of the gallery was mostly emergency exit area in case of fires, and my installation was declared as life threatening and dangerous by the fire inspector, because the wood were hanging in this area. Luckily the fire inspection was on the last day of the exhibition.

5.6 Enhancing the engaged experience in the fourth exhibition

While I had buried the thought of an interactive version, I got an opportunity after the airport exhibition to have my installation exhibited at the Annantalo Culture Centre. It was exiting, as it works as a culture teaching school to children. I was eager to find out how children would experience the installation.

First I had to make the installation as secure and safe as possible. I took off all of the metal plates and welded their loop hooks completely closed. I also changed all the screws of the wood pieces to extra long ones to hold even if the children would hang on the wood pieces.

For the sounds I only made a few changes with the animal sounds playing a little more often for the children to notice them. I also changed the heights of the hanging wood pieces a little lower so that the children would reach them. The stomp was bolted now also to the floor so that the children would not be able to move it around and so that the sound would resonate to the wooden floor.

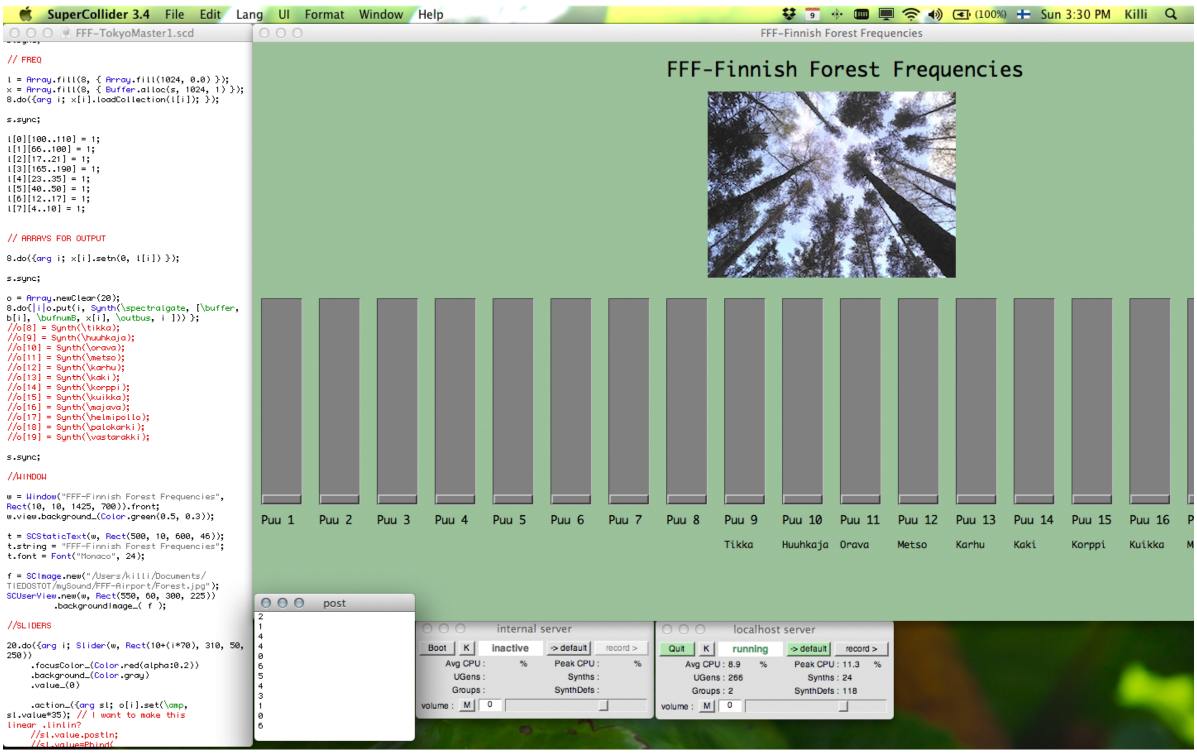

Figure 5.15 The final version of the SuperCollider code.

The space was beautiful with the wooden floor and staircase. This made me place the installation next to the staircase, because I realised that the reflections went all the way along the staircase to the first floor and the sounds were audible also there. The staircase would invite people to go into the forest.

Figure 5.16 Finnish Forest Frequencies with folding cosmos exhibition at Annantalo Culture Centre in Helsinki.

5.6.1 Challenges at the gallery

I did not have too many challenges. When setting up the installation, for the hanging, it had to be clarified whether it was possible to drill holes to the ceiling of a protected building. White small hooks were allowed to be placed to the white ceiling, and the hanging was a success. Only once the janitor had cut the power from the area while the communication between the staff was not clear. Also the exhibition time was quite short, and it would have been great to have it there longer, but unfortunately it was not possible. Overall the challenges were minor compared to other exhibitions, and this space sounded the best so far, as the surfaces did not include any soft materials.

5.6.2 Audience feedback of exhibition IV: Children vs. adults

Annantalo Culture Centre had a lot of teaching during the day for school classes of small children and also some evening time groups. As part of the classes, children gathered to listen to the installation and were asked to draw what they had heard. Some drew animals and some trees which were playing sounds. After asking the children if they would recognise the animal sounds, only a few were clear, such as the woodpecker and cuckoo. Other animals or birds were not recognised. And I noticed that this was actually the same with adults; only these few were recognised with certainty.

When the children were asked how they felt during the installation, they liked the calming experience and surprisingly replied by saying it was relaxing. This was a huge amazement for me. The children said exactly the same things as the adults. The main difference between the adults and children was that the children did not think about how the installation was technically made; they were not as interested about that, but instead they were keener about what the sounds were and why the installation was made. Also, the children liked to press their ears against the wood and listen to the sound within the wood longer and ran to do this to almost every wood piece. The adults mostly listened to only a single wood piece with their ear pressed against it.

Children also touched the wood much more easily that the adults, children were not afraid or embarrassed to hug the tree trunks. Overall, children were very excited about the installation, even though adults were as well, but their enthusiasm was clearly enjoyment. The children immediately wanted to go to a real forest to listen to sounds. I believe that children are not spending enough time in the nature, as one 10-year-old girl from Helsinki asked if the pieces of wood in the installation were made of plastic.

Figure 5.17 Children drew pictures of trees with sounds while listening to the installation.

Figure 5.18 Whole families enjoying the installation at Annantalo Culture Centre in Helsinki.

5.7 Conclusions

Everything started from the idea to bring the outside inside. I chose the Finnish identity, the forest, and turned it into a sound simulation as an installation where to feel and sense the atmosphere. People have always had an emotional relationship with the forest, as many spend their childhood next to the nature, and because the forest will heal and have a relaxing and calming effect. Nature has always been a part of the therapeutic treatments and also has a memorable effect. This narrative and layered effect became the focus point in the installation. The technical means came later and the tools were only used for the further development. The main goal was to create a space where people could forget everything else and be transferred to another state of mind.

The sound installation was not generative at first; the generativeness only came along later with the changes done to the sound design during the different development stages. The generativity was basically demanded by the work, it was needed in order to create the realness and narrative in the work. It was required, as the sounds were not plausible enough, the sound did not transfer the listener into another space, engage, immerse. Plausibility is needed for an emotional impact, even making the sound exotic and luring as a new experience, something almost like the wow-effect. The sound needed to be interesting enough to keep the listener spending longer periods of time listening to it, just like in a real forest. Also, as people wanted something big and great, I wanted to create that.

The complexity came along with these changes, because it was not easy the make the sounds ever changing and infinite. The system became a part of the aesthetic design, as it created a physical form for the sound; the sound vibrated through a material, the wood. I now find this concept as the beauty of the system, the design inside the design, which interacted with the space and the material. I used the space, the diffusion of it, and the materials' resonance to my benefit. The sound formed a connection with the other aspects of the design; with the wood material, the space, the atmosphere, and the narrative. It became a symbiosis when all of them were combined. The sound had created other and deeper levels of experiencing the sound.

All the exhibitions and the experiences derived from these have made me realise how important the generative sound design is in the creation of an extraordinary experience. All the feedback from the visitors, the process from the creation to the exhibition, and the feel of the space and material made the entire creation of the installation into a natural trajectory. It became more polished and more beautiful, meaningful, and interesting every day over time. After much iteration, I was able to point out what was relevant and required to make the sound installation intriguing, to make it beautiful. Through time, I gained the ability to notice the essential emotions in the listeners and emphasise them. Overall, it was easier to develop the installation further and to make it into what it needed to be in order to create those feelings in every listener.

In addition to the emotional impact, touch turned out to be one of the most meaningful things in the installation; touching and hugging the wood. By touching, the visitors clearly relaxed more, it opened them more to the experience. Along with the touch came the sound, being able to touch and feel the sound vibrations gave new subconscious levels to which I could entwine meanings. Hugging and preserving the sound was substantially serious, as this event has been attached to saving trees. For the sound it was also crucial; if the forests are taken down, the sounds of the forests will die. Therefore the wood emphasised the effect and the narrative which the sound was not capable of doing by itself.

The experience of the installation became a multimodal whole, a 4D with the sounds, the wood as the visuals, the touch, and the smell. And it was obvious that the people were engaged while seeing the installation; the immersion and transportation to the forest was possible with all these strong elements together. Even though the combination was something big, the pieces of wood were individuals; everyone seemed to notice the little details in the wood and in the sounds and chose their favourite one to hug. And I believe all this was only achieved in practice with the tools of generative sound design; without them the installation would not have been as engaging and successful.

5.8 Future development

Based on all my experiences I have decided to develop the installation further. I have decided to record all the animal sounds myself. Using library sounds makes me feel that the installation is not completely done by me. Therefore I recently made a trip to Kuusamo to record bears, birds, and forests in order to get the animal sounds as my own sounds to the installation. My future plan is to record as many wild Finnish animals and birds myself as possible. The forest also sounds different during different times of the year, which is why I wish to create each season of the forest sounds with its typical animal sounds. This only requires more time to record and get the sounds needed.

I will be striving to make the technical solutions more robust and easier to use, because of the technical problems and disturbances during the usage of the installation. I am also going to develop the technical system as easy to use for someone else, so that I will not be needed every time to set up the installation and to turn it on. In addition, I will be developing the software, which generates the sounds, into a stand-alone application and as user-friendly as possible. Wiring and cabling will also have a new visual protection design in the future in order to prevent the breakage and misuse of the cables an also to cover the technical equipment more. Overall, the technical problems will be solved and technical setup implementation will be developed further.

With the sound behaviour, I would like to try to attach some elements of timing to the sound design. The soundscapes could change according the time of the day, because the night sounds in a forest are completely different from the daytime sounds. This would add more generativity to the design and make it even more changeable.

In the future I would also like to make some listening tests of experiencing different nature sounds, research the experience with the touch, and make the soundscape more generative. Maybe even try the limits of realness with fantasy forest sounds. Also the cultural background of people perceiving the installation and the effect researched through cultural perceiving differences is an area, which could be studied more; the cultural or national background of the sounds and how they are being perceived in an environment installation.

6. Conclusion

Generative sound design can be seen as a process to create sound with always changing and new variational methods. The methods can be realised with the help of complexity, realness, and quality. These are the tools which enable to describe the creation process, and they have the ability to explicate the way the sounds are modified, manipulated, and designed in a generative sound design. Complexity, realness, and quality together form the basis and the idea structure of the generative sound design. However, it has become clear that complexity and realness are the bricks inside the quality process, because quality is the overall end result of the sound design entity.

Because I wanted to know whether the field of sound design would recognise the terms and concepts of generative sound design, I decided to interview sound design professionals. Based on the interviews, I am able to say that the majority of professionals already know what the generative sound design consists of. They all had similar answers, though with different words. Therefore it was noticeable that the terms and words for describing these processes have not gained any common norms, although many used the terms complexity, realness and quality directly or their synonyms in their answers. Mainly the ideas behind them were familiar but had no set phrases. Everyone understood the concept and was able to describe the process of generative sound, even if they had not implemented it themselves. However, to make the opinions for or against generative sound design were harder for those who had not. Therefore it is clear that the generative sound design is accepted and a known form of sound design. Also all of the interviewed professionals predicted that the generative sound design will have a bigger role in the future as being a relevant development process in many media formats.

Quality according to the interviewed was mainly thought of as an emotional aspect, the technology became irrelevant, as the level of technical quality is already high. This is why I wanted to know whether quality is more than the technical features in sound. This is because sound designers and audio engineers have been taught only the technical ways of handling the sound. The importance of designing the sound and its behaviour connected to the context and other aspects is crucial and important. The role of designing the sound in a generative context is even more highlighted, because the sound cannot be generative without the designing of the system and the way it makes the sounds behave. This automatically becomes a quality feature, the more fluent or clever the design of the system, the better the experience.

Therefore, in order to increase the quality in a sound design, the complexity and realness require a balance in their designs; they need to be designed in a way that their functionality suits and supports the purpose. That is why it does not matter how complex or real the design is, if it is plausible and immersive to the listener. Also, interactivity is not a necessity in generative sound design; sometimes an engaged experience is more suitable for the design, as I noticed during the making of the generative sound installation. All these aspects are only determined by the context, the story, and idea behind the sounds. Without the narrative, the sound design is purely sounds played one after another.

This is why I wanted to know how the generative sound design would be perceived, and if it would enhance the experience and interactivity. I wanted to know if and how people notice generative sound design and the quality of the design. It became obvious that the quality can only be measured accurately through the evaluation of the experience: how the listeners feel while listening or hearing the design. By creating a comparison test between a generative and a non-generative sound design, I could know if the listener would notice whether the sound design was produced as generative or not; if there were any noticeable differences. I also wanted to understand how the quality of sounds impacts the game design environment and interaction. I got an answer to all of these questions with my 3D environment research user test. I believe the results were significant, as I had 36 people from different ages and mainly without experience in sound or games.

The test proved that the generative sound design has more power over the experience. Even if the differences in the individual sounds were not hugely noticeable, the emotional impact was the determinant factor. Nevertheless, the difference between the generative sound design and the non-generative sound design was remarkable. The test users preferred the generative sound design as a better experience, and it is evident that the generative sound design is perceived differently emotionally and that it affects the interaction hugely, making it easier for the users. Even though the perception will always maintain its subjectivity, there are guidelines for similarities in the experiences of the listeners. Because audio is different from any other media, it can be perceived in many ways and still have similar outcomes as a result. It is not important to concentrate on the technology or the process per se, whether it would be algorithmic or any other method with which the sound was created. The most important factors are the emotions and the feelings that the sounds themselves create. Certain sounds and sound combinations do trigger the same emotional experiences in the listeners. I would say that this happened also with the majority of the test users, when they perceived the generative sound design, and according to the test results the experience was felt to be more interactive, rich, and natural; thus the generative sound design clearly enhanced the experience.

It is obvious that the generative sound design requires a design inside the sound design, because of its non-linearity. This sub-design includes the designing of the sound behaviour, which has become the essential part of generativity. The sound behaviour is the way the sound behaves with or without interaction and how it is connected to the other aspects of the design. The sound behaviour is implemented with mathematical, algorithmic, and rule-based methods in a system. These are the generative sound design process methods, and the generative system created with them is the engine or motor of the design. In order to create a generative design, these methods require a learning curve, and it is one of the key problems in making the generative sound design more used and implemented: the field is lacking in resources and knowledge. I wanted to discover what the advantages and disadvantages of generative sound design are, and through the study cases and the interviews I was able to discover that not only the emotional aspects speak in favour of the generative sound design, but also other aspects give the generativity more credit. Some of these benefits are the possibilities in creativity and the sounds behaving more realistically.

The engaging generative sound installation made an indelible impression on the listeners and visitors of the exhibitions, when the installation was most generative. In the first exhibition, the impact of the installation was not as powerful, but when the design developed and the sound gained more levels of influence, the wow effect was created. The most significant findings were that the more generative, the more real the sound of the forest became, and then the more relaxed the listeners were, and more importantly, this impacted not only adults but also children the same way. Children were very honest about their experiences and therefore it was easy to derive the impact of the design. With the adults, the experience of the sound design was felt in very deep levels, taking them back to childhood or memories. This made the listeners feel they experienced something unique and different; their memories made the experience personal and intimate.

During the generative sound design processes made for both study cases, I learned that this form of a sound design requires many iterations and testings, since the actual implementation is grounded on a special technology, sometimes self-made. It is more time-consuming, more difficult, and more expensive. Nevertheless, the final outcome is something unique, different, all the time changing, and intriguing. With the experience gained by making the study cases and the interviews, I can say that the advantages of generative sound design are much more valuable. In addition, the experience affects the determination between a good and bad sound design. Therefore generativity has turned into a value within this quality evaluation. It is fairly possible that the generative sound design as a value will make the users not to turn their sound off in applications and games.

This would mean that the generative sound design would increase the importance of sound design, making the sound function not only as a feedback, but also as an enhancer of the entertaining experience. I noticed during both study cases that the generative sound design increased the enjoyment, which is the measure for an entertaining experience. With generative sound design the wow effects can also be added more easily to the experience, and maybe it would also change the way we perceive sounds or at least change the attitude towards sounds and sound designs in the future. Maybe then the demand for better and quality sound designs would arise more as it has with visuals. In that case, the process would be accepted more easily to the project's creation processes and as part of the budgets.

6.1 Future research questions

The generative sound design perception has many aspects open for future study and research. Sound repetition and sound variety, including complexity and realness, have open questions about the sound manipulation recognition. People's ability to recognise the sound events and sound parts or loops that are repeated with different time spans, or how many sounds are needed in between not to realise the repeating sound being the same sound has not been fully studied. It would also be interesting to know what happens in the brain, when a person hears the same sound again, whether the person consciously realises it or does not recognise the same sound coming again.

I personally am not sure when the sound event or sound layering becomes too complex, and when the test users would indicate of this happening. Uncovering this limit of sound design becoming too messy would be absorbing to find out. As this complexity affects the realness, when are we in a situation that the generative sound in real time would sound as real as possible, how many variations, textures, randomness and other features are required, for instance of a natural element such as water. This could be realised with an interactive and generative sound installation, between with a very simple and looping, noticeable sound design and a design with more variety in sounds and a complex audio engine system. Measuring the time spent with the installation might prove how intriguing the experience to the people is. Their reaction could be measured and experiences interviewed. Also a listening comparison test with a real sound stream from a space and a reconstructed version of the same space would possible give answers whether people notice the difference.

There are quite many questions, which fall short whether they are philosophical or sound design related, and which are hard to separate while they are intertwined. The exploration of generative sound design perception has started, which hopefully obtains valuable cognisance now and in the future.

Appendix

ADVISORS

Koray Tahiroğlu – Research Fellow leading the Sound and Physical Interaction (SOPI) in the Department of Media, Media Lab, Aalto University School of Arts, Design and Architecture

Antti Ikonen – Lecturer of Sound Design and Music, in the Department of Media, Media Lab, Aalto University School of Arts, Design and Architecture

Opponent Jairo Acosta Lara - MA in Sound in New Media student

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ENCLOSED BLU-RAY WITH MEDIA

Photos by Kirsi Ihalainen, Mauri Tahvonen, Ricky Tourunen, Johanna Rotko, Finavia

Videos by Kirsi Ihalainen.

More photos and videos can be found online: http://kirsiihalainen.com

PROFESSIONALS INTERVIEWED

1. Timothy Nielsen – Sound Designer for films, Skywalker Studios
2. Olivier Deriviere – Composer for Interactive Video Game Music
3. Thomas Görne – Professor of Audio Design and Audio Systems, Media and Information Department Media Technology, Hamburg University of Applied Sciences
4. Elias Struck – Sound Designer and Audio Engineer, CEO Tonfabrik Audio Productions
5. Than Van Nispen – Interactive Music Strategist, lecturer at Utrecht University of the Arts
6. Edoardo Ciceri – Sound Designer and Composer for games and films
7. Joonas Turner – Game Sound Designer, E-Studio
8. Marianne Decoster-Taivalkoski – Sound Artist and lecturer at Music Technology, Sibelius Academy
9. Josue Moreno – Sound Artist and lecturer at Music Technology, Sibelius Academy
10. James Andean – Sound Artist and lecturer at Music Technology, Sibelius Academy
11. Peter Hajba – Game Sound Designer, Avalanche Studios

INTERVIEW QUESTIONS

<u>a) Sound Quality</u>

1. How do you understand sound quality and sound design quality, what do they mean to you?

2. What are the key elements to you in good sound design? What makes the sound design well/badly designed? What are the main factors to you of a good/perfect sound (when it comes to quality)?

3. How much do you care about sound quality? How do you perceive it or think how others would/should also perceive it?

4. What is your own sound quality process in your sound design work?

5. What is the aim of how you want the people to perceive your sound design and why? What are you taking into account to achieve this?

6. What media/art format do you think has the least and most importance when it comes to sound design quality and why?

b) Generative Sound Design

7. How do you understand generative sound design and what does it mean to you? What is the limit of sound becoming generative?

8. What do you think are the benefits or disadvantages of having a generative sound design?

9. What makes a good and a bad generative sound design and why? What are the most important factors to you in generative sound design?

10. Do you use generative sound design essentially in your own works? If yes, then why, in what purpose, extent, and how? If not, then for what reason?

11. How do you think generative sound design is being perceived and what are the attitudes towards it?

12. How do you think the generative sound design affects the experience, the interactivity and the visuals?

13. Do you think generative sound design is being utilised enough? To get more generative sound designs out there, what would need to be done or fixed?

c) Sound Complexity and Realness

14. What does sound complexity mean to you and how do you understand it? What would a very complex sound and complex sound design be like? Describe what the complexity in your own sounds is?

15. What does realness mean to you and how do you understand it? How do you distinguish what sounds feel real or unreal to you? Are there any real and unreal sounds to you? What is the realness in sound to you?

16. Do you use library sounds or record your own sounds? How about synthesized/ procedural sounds? Which do you prefer and which ones feel more real to you?

17. Do you pay attention to complexity and realness of the sounds in your own work? Why and how?

d) Game Sound (Extra questions only for Peter Hajba)

18. What is the game audio quality process like in your company? What are the demands and guidelines about audio and its quality in you company?

19. What are the main audio tools that will ensure the audio quality in the games of your company?

20. If your company uses generative audio, what are the generative audio tools that are used in your company?

21. What is the present state and what will be the future of game audio?

Extra fun question:

22. What is the best sound design ever that you have heard or encountered? Can be your own or someone else's.

STUDY CASE 1: 3D ENVIRONMENT

User testing place and dates

The 9th-14th of July 2015, Lume Media Centre Sound Studios, Äänimaa, sound studio room number 117

Test users

From the cities of Helsinki and Tampere, between the ages of 11-51. Both female and male with and without background in games or sound.

Contributors

3D environment modelling and programming by Alexander Nikulin.
Foley artist and sound assistant Vili Laitinen.
Sound programming assistant by Esa Tanskanen.

The contributors to organise the 3D environment user test spaces with me were: Juha Tanhuanpää and Birgitta Rosti-Pylkkänen.

Special thanks to the 36 test users.
Tools by FMOD, RX iZotope, Unity, Media Lab, and Lume Media Centre Sound Studios.

User test questions

3D Environment

Basic information

1. I give my permission to use my answers of this research test and photos/videos taken during the test to be used in Kirsi Ihalainen's thesis. (Identity will not be published.) *

☑ Yes

2. Gender *

◉ Male

○ Female

3. Age

0 Years

4. Background

	No background	Beginner	Some skills	Skilled	Expert
in sound	○	○	○	○	○
in games	○	○	○	○	○
in interactivity	○	○	○	○	○

Questions relating to the Environment 1 session:

5. How many sounds felt repetitive to you in the Environment 1: *

◉ None ○ 1-2 ○ 3-5 ○ 5-10 ○ Over 10

6. If any, can you identify which sounds?

7. How many of the sounds were irritating you during Environment 1: *

◉ None

○ 1-2

○ 3-5

○ 5-10

○ Over 10

8. If any, can you identify which sounds?

9. How well did you feel the sounds were fitting the environment? *

	0	1	2	3	4	5	
Not at all	○	○	○	○	○	○	Excellently

10. From the Table below, please select the adjectives, which best describe the overall experience of Environment 1: *

☑ Enjoyable ☐ Delightful ☐ Pleasant ☐ Interactive ☐ Horrible ☐ Active ☐ Awkward ☐ Satisfying ☐ Engaging ☐ Friendly

☐ Disappointing ☐ Intimidating ☐ Organised ☐ Frustrating ☐ Energetic ☐ Chaotic ☐ Surprising ☐ Predictable ☐ Boring ☐ Amazing

11. How much did you like the sounds in Environment 1: *

	0	1	2	3	4	5	6	7	8	9	10	
Not at all	○	○	○	○	○	○	○	○	○	○	○	A lot

12. Could you explain more about the characteristics of sound you noticed in the Environment 1: *

-

Questions relating to the Environment 2 session:

13. How many sounds felt repetitive to you in the Environment 2: *

(•) None ( ) 1-2 ( ) 3-5 ( ) 5-10 ( ) Over 10

14. If any, can you identify which sounds?

15. How many of the sounds were irritating you during Environment 2: *

(•) None
( ) 1-2
( ) 3-5
( ) 5-10
( ) Over 10

16. If any, can you identify which sounds?

17. How well did you feel the sounds were fitting the environment? *

	0	1	2	3	4	5	
Not at all	( )	( )	( )	( )	( )	( )	Excellently

18. From the Table below, please select the adjectives, which best describe the overall experience of Environment 2: *

[x] Enjoyable	[ ] Delightful	[ ] Pleasant	[ ] Interactive	[ ] Horrible	[ ] Active	[ ] Awkward	[ ] Satisfying	[ ] Engaging	[ ] Friendly
[ ] Disappointing	[ ] Intimidating	[ ] Organised	[ ] Frustrating	[ ] Energetic	[ ] Chaotic	[ ] Surprising	[ ] Predictable	[ ] Boring	[ ] Amazing

19. How much did you like the sounds in Environment 2: *

	0	1	2	3	4	5	6	7	8	9	10	
Not at all	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	A lot

20. Could you explain more about the characteristics of sound you noticed in the Environment 2: *

-

Questions relating to the comparison between Environment 1 and 2 sessions:

21. What differences did you notice or feel in the sounds when comparing the environments? *

22. How did the sound affect your experience and interaction with the environments?

*23. Which one of the environments did you prefer? **

- ○ Environment 1
- ○ Environment 2
- ○ I do not know

*24. How much do you normally pay attention to sounds while playing games? **

	0	1	2	3	4	5	
Not at all	○	○	○	○	○	○	A lot

*25. What was your overall experience of the entire user test? **

STUDY CASE 2: SOUND INSTALLATION

Exhibitions and dates

The Landscape in our Memory (26.1.-1.2.2015) Annantalo Arts Centre, Helsinki, Finland

Chimes of Deadwood and Life on Agar Plates (29.10.-21.11.2014) AMF-Gallery, Media Factory, Helsinki, Finland

Finnish Forest Frequencies (5.6.2014-14.1.2015) Kainuu lounge, Helsinki Airport, Helsinki, Finland

自然 / *Luonto / Nature* (1.-6.5.2014) SICF-festival, Spiral Gallery, Tokyo, Japan

Ladon Uni (House of Sleep) (18-22.9.2013), Habitare Design Competition: second place, Helsinki Exhibition and Convention Centre, Finland

FFF-Finnish Forest Frequencies (24.-26.5.2012), Northern World Mandate seminar, School of Arts, Design and Architecture, Aalto University, Helsinki

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References

Altman, R. (1992). *Sound theory sound practise.* New York: Routledge.

Ament, V.T. (2009). *The foley grail: the art of performing sound for film, games, and animation.* Burlington USA: Focal Press.

Andean, J. (2015). Interview with A. Hatton on 19th May 2015. Helsinki. [Recording in possession of author]

Archimago. (2014.) *24-Bit vs. 16-Bit Audio Test - Part II: RESULTS & CONCLUSIONS* [Online] June 27th 2014. Retrieved August 16, 2014, from http://www.mcelhearn.com/well-crafted-study-shows-listeners-cannot-distinguish-between-cd-quality-and-high-resolution-music-files/

Aro, E. (2006). *Tilaääni*. Helsinki: Riffi-julkaisut.

Beilharz, K. (2004). Designing Generative Sound for Responsive 3D Digital Environment Interaction, Retrieved November 3, 2014, from http://cumincad.architexturez.net/system/files/pdf/502caadria2004.content.pdf

Bigelow, J., & Poremba, A. (2014). Achilles' Ear? Inferior Human Short-Term and Recognition Memory in the Auditory Modality. 10.1371/journal.pone.0089914. Retrieved March 6, 2015, from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0089914

Bijsterveld, K. (2006). Listening to machines: Industrial noise, hearing loos and the cultural meaning of sound. In T*he Sound Studies Reader.* UK: Routledge. p. 152-167.

Böttcher, N., Martinez, H.P., & Serafin, S. (2013). Procedural Audio in Computer Games Using Motion Controllers: An Evaluation on the Effect and Perception. Retrieved August 8, 2015, from http://www.hindawi.com/journals/ijcgt/2013/371374/

Chagas, P.C. 2006. Virtuality and Metadesign: Sound Art in the Age of Connectivity. *Music, Meaning, and Media.* Acta Semiotica Fennica XXV. Approaches to Musical Semiotics 11. Editors: Erkki Pekkilä et al. Helsinki: International Semiotics Institute, p. 137-153.

Chion, M. (1994). The Three Listening Modes. Translated by C. Gorbman. In *The Sound Studies Reader.* UK: Routledge. p. 48-53.

Ciceri, E. (2014). Thesis interview questions. [Interview]. 6th July 2014.

Collins, K. (2008). *Game Sound, An Introduction to the History, Theory, and Practice of Video Game Music and Sound Design.* Massachusetts: The MIT Press.

Collins, K. (2013). P*laying with Sound, A Theory of Interacting with Sound and Music in Video Games.* Massachusetts: The MIT Press.

Crawford, K. (2009). Following you: Disciplines of Listening in Social Media. In *The Sound Studies Reader.* UK: Routledge. p. 79-90.

Csound, (2015). About. Retrieved March 8, 2015, from http://csound.github.io/about.html

Cunningham, S., Grout, V., & Picking, R. (2011). Emotion, content and context in sound and music . In Grimshaw, M. (Ed.) *Game sound technology and player interaction: Concepts and developments.* Hershey, PA: IGI Global.

Decoster-Taivalkoski, M. (2014). Interview with M. Decoster-Taivalkoski on 24th November 2014. Helsinki. [Recording in possession of author]

Deriviere, O. (2014). Interview with O. Deriviere on 30th June 2014. Hamburg. [Recording in possession of author]

Diefenbach, S., Lenz, E., & Hassenzahl, M. (2013). An interaction vocabulary. Describing the how of interaction. In CHI'13 Extended Abstracts on Human Factors in Computing Systems, p.607-612. ACM.

Di Scipio, A. (2003). 'Sound is the interface': from interactive to ecosystemic signal processing. Retrieved 19 November, 2015, from: https://www.ak.tu-berlin.de/fileadmin/a0135/Unterrichtsmaterial/Di_Scipio/Sound_is_the_interface.PDF

Ekman, I. (2008) *Psychologically Motivated Techniques for Emotional Sound in Computer Games.* Proc. AudioMostly 2008, October, Piteå, Sweden, 20-26. Retrieved March 8, 2015, from https://meaningfulnoise.wordpress.com/psychologically-motivated-techniques-for-emotional-sound-in-computer-games/

Eriksson, M. (2015). *Mitä Äänen koulutusohjelma tarkoittaa?* Meteli 1/2015, p. 32-33.

Essl, K. (2013). REplay PLAYer. Retrieved August 8, 2015, from http://www.essl.at/works/replay.html

Farlex Inc, (2014). *The free dictionary.* Retrieved November 3, 2014, from http://www.thefreedictionary.com/generative

Farnell, A. (2007). *An introduction to procedural audio and its application in computer games.* Retrieved November 3, 2014, from http://www.cs.au.dk/~dsound/DigitalAudio.dir/Papers/proceduralAudio.pdf

Farnell, A. (2008). *Designing Sound.* London: Applied Scientific Press Ltd.

Franinovic, K., & Serafin, S. (2013). *Sonic Interaction Design.* Massachusetts: The MIT Press.

Franinovic, K., & Salter, C. (2013). The experience of Sonic Interaction. In *Sonic Interaction Design.* Massachusetts: The MIT Press. p. 39-75.

Filmtrip (2013). *Biosuite & Unsound.* Retrieved November 10, 2014, from http://www.filmtrip.tv/work/entry/biosuite-emotional-response-cinema/

FMOD, (2015). *FMOD.* Retrieved January 15, 2015, from http://www.fmod.org

Gaver, W.W. (1988). Everyday Listening and Auditory Icons. Dissertation, San Diego: University of California.

Garton, A. (1996). *Towards Generative Sound for Interactive Multimedia*. Master of Arts Research. Australia: RMIT University.

Gibbs, T. (2007). The Fundamentals of Sonic Art & Sound Design. Switzerland: Ava Publishing SA.

Giordano, B.L., Susini, P., & Bresin, R. (2013). Perceptual Evaluation of Sound-Producing Objects. In Franinovic, K., Serafin, S. (2013). *Sonic Interaction Design.* Massachusetts: The MIT Press. p.151-197.

Görne, T. (2014). Interview with T. Görne on 3rd July 2014. Hamburg. [Recording in possession of author]

Hajba, P. (2015). Thesis interview questions. [Interview]. 18th July 2015.

Ihde, D. (1974) The Auditory Dimension. In T*he Sound Studies Reader.* UK: Routledge. p. 23-28.

Ikonen, A. (2011). *Keinoäänten jäljillä. Ääniympäristön muutoksesta digitaalisen aikakauden ensivuosikymmeninä.* Masters Thesis. Finland: Pori Unit of the Department of Art, Aalto University.

Impromptu, (2015). What is Impromptu? Retrieved March 8, 2015, from http://impromptu.moso.com.au/

Izhaki, R. (2012). *Mixing audio concepts, Practices and Tools.* Oxford, GB: Elsevier Ltd.

Kinnunen, A. (2000). *Estetiikka*. Juva: WSOY.

Lapington, R. (2006). *Designing Audio Content for NC4C Cell 22 Prototype Next Generation Platform Game.* Masters Thesis. Finland: Aalto University.

Larsen, A.H.R. (2008). *East is Red: semi-generative audiovisual composition, composed instrument part of the Audio Visual Live Composition System.* Master's Thesis. Finland: Aalto University.

Liljedahl, M. (2011). Sound for Fantasy and Freedom. In Grimshaw, M. (Ed.) *Game sound technology and player interaction: Concepts and developments.* Hershey, PA: IGI Global.

Lu L., Li S., Wenyin, L., & Zhang, H. (2002). Audio Textures Retrieved November 3, 2014, from http://www.cs.cityu.edu.hk/~liuwy/publications/AudioTextures_ICASSP.pdf

Marks, A. (2001). *The complete guide to Game Audio, for Composers, Musicians, Sound Designers, and Game Developers.* Kansas, USA: CMP Books.

Monster Cable (1998). *The Monster meet filmmaker David Lynch.* Retrieved March 4, 2015, from http://www.lynchnet.com/monster.html

Moreno, J. (2015). Interview with J. Moreno on 30th April 2015. Helsinki. [Recording in possession of author]

Moss, R. (2015). Creative AI: Software writing software and the broader challenges of computational creativity. Gizmag. Retrieved March 8, 2015, from http://www.gizmag.com/creative-ai-computational-creativity-challenges-future/36353/

Naimark, M. (1990). Realness and Interactivity. The Art of Human Computer Interface Design, NY: Addison Wesley. Retrieved April 20, 2015, from http://www.naimark.net/writing/realness.html

Nair, V. (2014). What's The Deal With Procedural Game Audio? [Online]. 31st October 2014. Retrieved August 8, 2015, from http://designingsound.org/2014/10/whats-the-deal-with-procedural-game-audio/

Neurogadget, (2011). MyndPlay lets you control Movies with mindWave headset. Retrieved March 15, 2015, from http://neurogadget.com/2011/03/06/myndplay-lets-you-control-movies-with-mindwave-headset/1287

Nielsen, T. (2014). Interview with T. Nielsen on 3rd July 2014. Hamburg. [Recording in possession of author]

Nilsson, A. (2012). "The 'realness' of unidentified sound objects- the perception of sound in contemporary horror films". Course study, Stockholm University. Retrieved April 21, 2015, from https://andrewmusic.files.wordpress.com/2013/10/uso-in-horror-a-nilsson-2012.pdf

Nispen, T. V. (2014). Thesis interview questions. [Interview]. 13th July 2014.

O'Keeffe, L. (2010). Sound is Not a Simulation: Methodologies for Examining the Experience of Soundscapes. In Grimshaw, M. (Ed.) *Game sound technology and player interaction: Concepts and developments.* Hershey, PA: IGI Global.

Priestley, J. (2014). *Poiesthetic play in generative music.* VCU Theses and Dissertations. Paper 3403. Retrieved March 8, 2015, from http://scholarscompass.vcu.edu/cgi/viewcontent.cgi?article=4402&context=etd

Procedural Audio Now, (2014). Procedural Audio Now! Retrieved 9th August, 2015, from http://proceduralaudionow.com/

Reiter, U. (2011). Perceived Quality in Game Audio. In Grimshaw, M. (Ed.) *Game sound technology and player interaction: Concepts and developments.* Hershey, PA: IGI Global.

Rettner, R. (2010). Brain's Link Between Sounds, Smells and Memory Revealed. [Online]. 5th August 2010. Retrieved May 4, 2015, http://www.livescience.com/8426-brain-link-sounds-smells-memory-revealed.html

Saint-Arnaud, N. (1995). Sound Textures and *Analysis and Synthesis of Sound Textures.* Retrieved May 26, 2015, from http://xenia.media.mit.edu/~nsa/SoundTextures/ and http://xenia.media.mit.edu/~nsa/SoundTextures/Saint-Arnaud+Popat1998_SoundTexturesResynthesis.pdf

Schafer, R. M. (1994). The Soundscape: our sonic environment and the tuning of the world. Rochester, Vt: Destiny Books.

Shneiderman, B. (2002) Leonardo's Laptop: Human Needs and the New Computing Technologies, MIT Press.

Schnell, N. (2013). *Playing (with) Sound, Of the Animation of Digitized Sounds and their Reenactment by Playful Scenarios in the Design of Interactive Audio Applications.* Dissertation. Austria: University of Music and Performing Arts Graz.

Schine, J. (2010). *Movement, memory & the senses in soundscape studies.* Retrieved March 6, 2015, from http://www.sensorystudies.org/sensorial-investigations/movement-memory-the-senses-in-soundscape-studies/

Sonnenschein, D. (2001). *Sound design: the expressive power of music, voice, and sound effects in cinema. Studio City, CA, Michael Wiese Productions.*

Sterne, J. (2012) *The Sound Studies Reader.* Suffolk, UK: Routledge.

Struck, E. (2014). Interview with E.Struck. on 4th July 2014. Hamburg. [Recording in possession of author]

SuperCollider. (2015). SuperCollider. Retrieved January 15, 2014, from http://supercollider.github.io/

Tahiroğlu, K. et al. (2014) *SoundFLEX: Designing Audio to Guide Interactions with Shape-Retaining Deformable Interfaces.* In ICMI '14 Proceedings of the 16th International Conference on Multimodal Interaction. p.267-274. ACM.

The Sound Agency (2014). *The Ambifier.* Retrieved November 3, 2014, from http://www.thesoundagency.com/the-ambifier/

Toprac, P., & Abdel-Meguid, A. (2011). Causing fear, suspense, and anxiety using sound design in computer games. In Grimshaw, M. (Ed.), *Game sound technology and player interaction: Concepts and developments.* Hershey: IGI Global.

Turner, J. (2014). Interview with J.Turner on 27th August 2014. Helsinki. [Recording in possession of author]

Visell, Y., Murray-Scmith, R., & Brewster, S.A. (2013). Continuous Auditory and Tactile Interaction Design. In Franinovic, K., Serafin, S. (2013). *Sonic Interaction Design.* Massachusetts: The MIT Press. p.77-124.

Veale, K. (2012). *"Interactive Cinema" Is an Oxymoron, but May Not Always Be.* Retrieved November 3, 2014, from http://gamestudies.org/1201/articles/veale

Weir, P. (2014). Never-Ending Audio: Generative Sound in Games. Talk at Indievelopment 2014. retrieved March 8, 2015, from https://vimeo.com/91805298

Wyse, L. (2005). *Generative Sound Models.* Retrieved November 3, 2014, from http://www.zwhome.org/~lonce/Publications/Publications_files/Wyse_MMM_GenerativeSoundModels_IEEE.pdf

List of figures

Figure 5.17. Children drew pictures of trees with sounds while listening to the installation. [Photograph].

Figure 5.18. Whole families enjoying the installation at Annantalo Culture Centre in Helsinki. [Photograph].